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Observations of Hippopotamus H. amphibius in the Little Scarcies River of Sierra Leone and Arguments for their conservation based on roles they play in riverine grasslands and nutrient loading

Lindsey R. Perry
Michigan Technological University, lrperry@mtu.edu

OBSERVATIONS OF HIPPOPOTAMUS *H. AMPHIBIUS* IN THE LITTLE SCARCIES RIVER OF SIERRA LEONE AND ARGUMENTS FOR THEIR CONSERVATION BASED ON ROLES THEY PLAY IN RIVERINE GRASSLANDS AND NUTRIENT LOADING

By

Lindsey R. Perry

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Report Advisor:	*Casey J Huckins PhD*
Committee Member:	*Amy M. Marcarelli PhD*
Committee Member:	*John A. Vucetich, PhD*
Department Chair:	*Chandrashekhar P. Joshi PhD*

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Abstract

A small population of *Hippopotamus amphibius* remains in Sierra Leone and conservation efforts may be needed to support the Hippos and their indirect benefits to fisheries and grassland production. The hippo is a known ecosystem engineer, and a potentially important contributor of nutrients to the river systems they inhabit supporting the food web and local fisheries. In this study I observed hippos in the Little Scarcies River and uplands of the Outamba-Kilimi National Park to estimate their numbers and ultimately their potential input of nutrients into the river. Hippos forage at night in grasslands neighboring rivers, removing up to 3.62 ha of annual production, but spend most of the day submerged in the river. The group of hippos observed in this study contained up to 12 individuals, estimated to be contributing approximately 44 kilograms of wet matter (feces) into the river each day, liberating approximately 8 kg of dissolved organic carbon, 1.14 kg of total nitrogen, and 0.14 kg (140 g) of total phosphate to the Little Scarcies River. Because of these valuable nutrient contributions, as well as other ecosystem services provided by their movements and interactions with other species, hippopotami should be closely monitored and protected. Park management includes a buffer zone that has been created to mitigate anthropogenic changes to hippo habitat and ensure survival of the population, and with proper enforcement could help hippo populations. The results of this study are presented in the context of the broader picture of hippo conservation in Sierra Leone.

Introduction

The *Hippopotamus amphibius* (common hippopotamus) population in Sierra Leone is isolated, listed as vulnerable by the IUCN, and requires consideration due to its small population size and likely important role in the river ecosystems of the country. Since becoming an independent nation, Sierra Leone has struggled to develop a working environmental conservation strategy as it has been routinely set back by economic crises, civil war, and most recently a disease outbreak. As a result, little attention has been paid to the juxtaposition of human population growth and natural resource extraction. The majority of the Sierra Leone human population relies on subsistence farming for survival, and as the population increases, more and more land is being converted into farms. A subset of the hippos of Sierra Leone are persisting in the Great and Little Scarcies Rivers with watersheds that drain about 22% of the country, and includes almost 10,000 square kilometers of agricultural land in the Northern Province of the country (Teleki, 1986). These river systems are extremely important for the daily survival of people within the region and they are also important habitat for common hippopotamus. Because of population growth and spread, hippo habitat is in danger of being eliminated (Teleki, 1986). Defining and enforcing conservation methods to ensure future availability of the country's natural resources such as its hippopotamus population may provide vital feedbacks such as fertilization of local waters, boosting fisheries production that indirectly support the human population. In this study I surveyed a group of hippos in the Little Scarcies River, Sierra Leone, and mapped their onland trails to their grassland feeding grounds to estimate their potential nutrient inputs into the river and the extent of their foraging, and thus impact on ecosystem productiveness.

Sierra Leone

Sierra Leone (Figure 1) is a small country (71,740 km^2) located in the Guineo-Congolian ecoregion of West Sub-Saharan Africa ("The World Factbook", 2013). It borders the Atlantic Ocean, Guinea and Liberia and is approximately the size of South Carolina.

Figure 1. The Republic of Sierra Leone, West Africa. Reprinted from Africa: Sierra Leone, In *Central Intelligence Agency: The World Factbook*, n.d., Retrieved March 21, 2015, from https://www.cia.gov/library/publications/the-world-factbook/geos/sl.html.

The capital of Sierra Leone is Freetown, which is located in the Western Area on the coast. Approximately 5% of the country is currently forested (Figure 2), which is a severe drop from the historical estimates of 70% cover (“Biodiversity Analysis,” 2007). The land is being largely converted into farm bush, which is a result of slash-and-burn agricultural practices (“Biodiversity Analysis,” 2007). Logging, production of firewood, and mining were ranked as the primary sources of land degradation in 2004 (“Biodiversity Analysis,” 2007), and began as far back as the 1800’s when the British Navy relied on Sierra Leone timber to build ships for the slave trade (Squire, 2001).

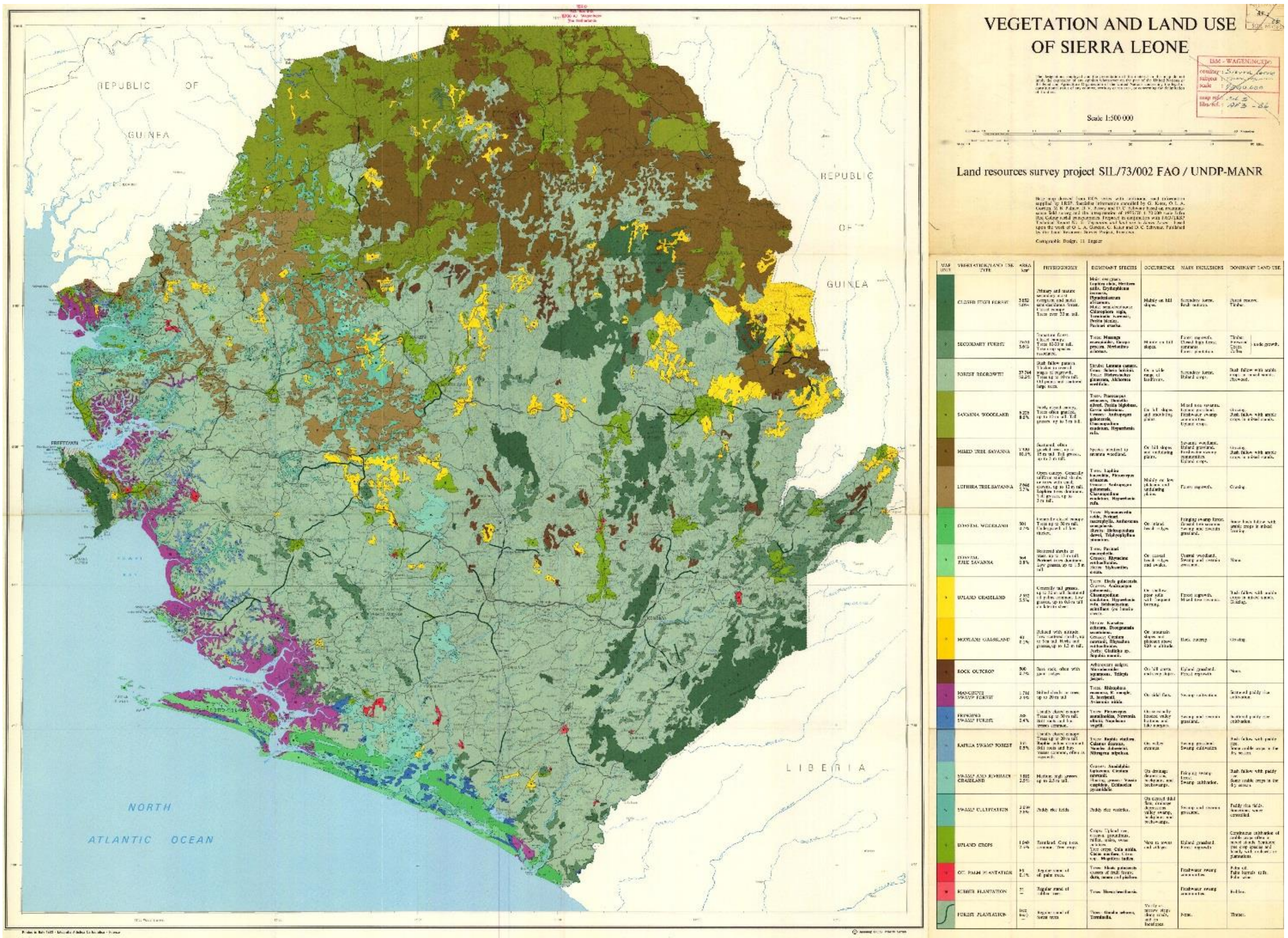


Figure 2. Vegetation and land use map of Sierra Leone showing primarily savannah woodland and mixed tree savanna within the boundaries of Outamba-Kilimi National Park. Reprinted from *The Soil Maps of Africa*, by O.L.A. Gordon et al., 1980, Retrieved February 16, 2015 from http://eusoils.jrc.ec.europa.eu/esdb_archive/eudasm/africa/lists/csl.htm. Copyright 1980 by United Nations Development Programme.

Sierra Leone is considered a tropical savannah climate, with a distinct rainy season and dry season (Figure 3). The rainy season lasts from May to November, bringing 300 to 1000 mm of rain per month (McSweeney, New, & Lizcano, n.d,). Coastal rainfall can reach up to 495 cm per year, although levels vary throughout the country. During the dry season there is often no rain, and drinking wells and streams commonly dry up.

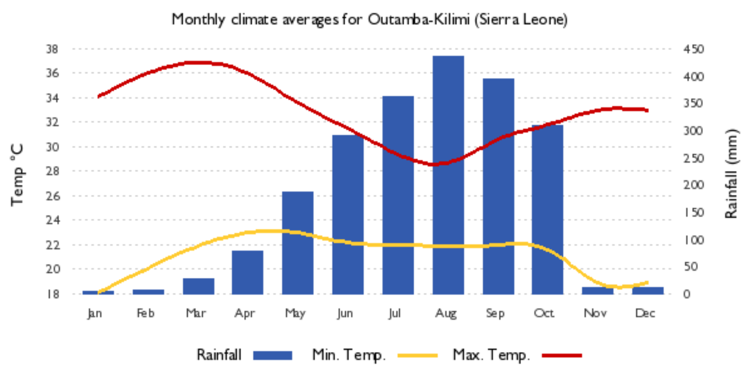


Figure 3. Average monthly temperature and rainfall for Outamba-Kilimi National Park. Reprinted from Protected Areas Report - Overview of Outamba-Kilimi, n.d., Retrieved February 1, 2015 from http://bioval.jrc.ec.europa.eu/PA/pa/7417/PA_report_7417.html. Copyright 2008 by European Communitie

There is relatively small elevation change throughout the country, with the lowest point being sea level and the highest point being 1948 m in the Loma Mountains ("The World Factbook," 2013).

Fishing is an important source of food for Sierra Leoneans, with fish providing 70% of the nation's protein requirements (Carew-Reid et al., 1993). There are 10 major rivers (Figure 4) that flow from the north-east to the mangrove swamps along the coast of the Atlantic Ocean (Squire, 2001).

Figure 4. Map of Sierra Leone, including all major rivers. Reprinted from worldofmaps.net, by Globe-trotter, n.d., Retrieved March 23, 2015, from http://www.worldofmaps.net/en/africa/map-sierra-leone/map-sierra-leone-download.htm. Copyright n.d. by Creative Commons Attribution-Share Alike 3.0.

Human use of the flood plains of these rivers are extensive, especially for the Scarcies (Great Scarcies, or Kolente, and Little Scarcies Rivers) watershed in the Northern Province. Rivers and streams are used for bathing, watering animals and many other daily tasks. Human and animal waste are often dropped in the water, along with trash since there are no other methods practiced for trash disposal. The rivers are used to transport fish and other small goods for sale, and sand dredging for building materials is practiced in the same areas.

Hippos in Sierra Leone

West Africa does not have much ideal habitat for hippos (Figure 5), which may be the reason for the isolation of populations within the region (Eltringham, 1999). Only very few surveys of wildlife in Sierra Leone have been conducted in the past 50 years; however based on this data the hippo population seems to be relatively stable over the last several decades (Table 1). As early as 1968, the Great Scarcies, Little Scarcies, and Kaba rivers were thought to be the only places in Sierra Leone where hippos still existed (Robinson, 1971), although they were reported at least once in the brackish waters near the Little Scarcies river basin (Clarke, 1953). It can only be assumed then, that the population hasn't moved from these river sites, as they would have to travel a great distance (approximately 200 km) to reach the next river system, which is unlikely.

Table 1. Estimated hippopotamus population sizes in the Little

Source	Estimated Hippo Population
Teleki, 1979/80	130-190
Teleki, 1986	200-280
Eltringham, 1999	200
Eltringham, 1999	100
Lewison & Oliver, 2008	100

Figure 5. The common hippopotamus, Reprinted from *Africa Waterhole: Hippopotams,* by H.V. Davis, n.d., Retrieved March 23, 2015, from http://www.mnh.si.edu/mammals/pages/where/africa/hippo_info.htm. Copyright n.d.California Academy of Sciences.

Hippopotamus Ecology

Hippos are commonly referred to as “ecosystem engineers” due to the many roles they play in physically and chemically shaping an ecosystem (Wright & Jones, 2006). The IUCN stated the common hippo to be “a critical element to the overall preservation of Africa’s wetlands” (Lewison & Oliver, 2008). They directly and indirectly impact their ecosystem in many important ways. Hippos convert biomass (grass) into usable forms of fertilizer in river systems (Mosepele, Moyle, Merron, Purkey, & Mosepele, 2009). They create and/or maintain a “mosaic of habitat” for other organisms, which promotes biodiversity in the area (Figure 6); (Lewison & Carter, 2004);

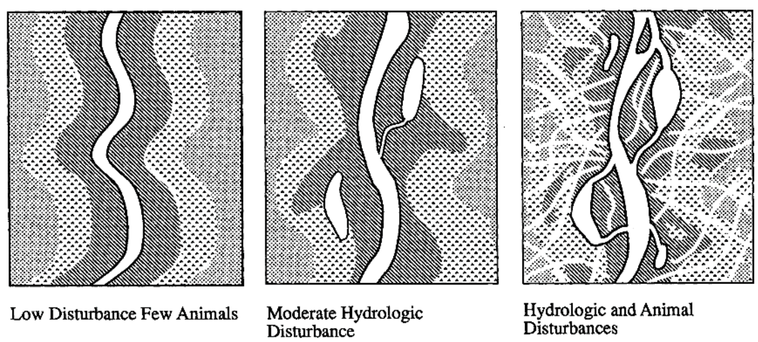


Figure 6. River systems with (a) few animals and channel management, (b) natural channel hydrology and processes, and (c) with the influence of movement and foraging of large animals. Reprinted from “Large Animals and System-Level Characteristics in River Corridors,” by R.J. Naiman and K.H. Rogers, 1997, *BioScience, 47(8)*, p. 523. Copyright 1997 by Oxford University Press on behalf of the American Institute of Biological Sciences. Reprinted with permission.

Similarly, hippos create and maintain channels between water sources (McCarthy, Ellery, & Bloem, 1998), important for movement of fish, amphibians, and nutrients. Foraging hippos maintain short grass levels, or “hippo lawns” that benefit other wildlife by providing a resource that reduces competition and predator-prey interactions, which may then reduce availability of bushmeat needed to feed local people. This also creates space for other herbivores to selectively forage on otherwise covered and/or dangerously located vegetation (Kanga, Ogutu, Piepho, & Olff, 2011). Predators are able to use areas of tall grass cover to discretely hunt for prey, and the reduction of tall grasses opens the visibility for smaller grazers. The same hippo trails that create grassland mosaics and connect waterways also create fire barriers, which reduce spread of bush fires during the dry season (Eltringham, 1999). Without hippos present, grasses grow to heights of over five meters that are susceptible to extremely hot and far reaching bush fires (Hough, 2007). Hippos also interact with other species in a commensalistic relationship. They move river substrates that provide places for birds and small crocodiles to rest where they are safe from predators and create areas for predators to feed on fish production enhanced by hippo dung (Eltringham, 1999). They also create deep pools by causing erosion of sediments on the bottom of the water source that are transported downstream (Naiman & Rogers, 1997), opening up habitat for animals such as crocodiles and fish and reducing evaporation for a long-standing water source. This stirring up of sediments and nutrients also helps prevent anoxic conditions (Mosepele et al., 2009). Lastly, hippos contribute nutrients to river systems, which fuel primary production and the food web that support fish populations (Figure 7), (Mosepele, Moyle, Merron, Purkey, & Mosepele, 2009).

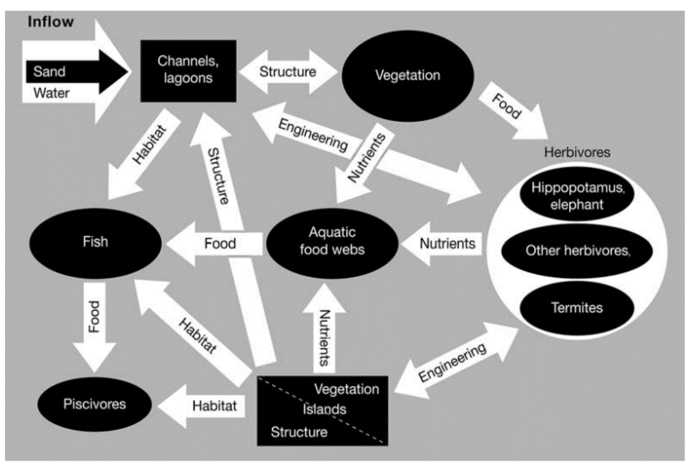


Figure 7. A model showing biological and physical interactions between the Okavango Delta ecosystem and fish species. Reprinted from “Fish, Floods, and Ecosystem Engineers: Aquatic Conservation in the Okavango Delta, Botswana,” by K. Mosepele et al., 2009, *BioScience, 59(1)*, p. 59. Copyright 2009 by American Institute of Biological Sciences. Reprinted with permission.

Naiman and Rogers (1997) stated “the exclusion or removal of elephants and hippopotamus from river corridors in Africa has led to pools filling with sediment, the closure of riparian forest canopies, and altered species composition.” As hippos alter their historical and/or current paths, or create new ones, a mosaic is created (Figure 6). The dynamic sets of pools and channels that hippos create are highly utilized by fish (Wright & Jones, 2006).

Conservation Status Worldwide

Hippos have been known to be highly sensitive to environmental changes, specifically changes in rainfall (Lewison, 2007). The overall population of hippos in Africa is declining, showing a 7-20% decrease in total numbers (Kendall, 2011), despite the need for periodic culling exercises in one or two countries (Eltringham, 1999). Anthropogenic changes are compounding the effects of natural stressors placed on hippo populations such as drought (Lewison, 2007). Climate change as well as human population expansion and growth should be considered along with the common threats to hippos in order to completely assess the future of each hippo population. While in some areas of Africa water supply seems to be the limiting factor for populations, hippos located in areas that do not experience drought seem to be limited by the food supply available at that location (Harrison, Kalindekafe, & Banda, 2007), particularly in the dry season. With the increase in human populations, expanding and creating agricultural land, hippo habitat is vulnerable.

Habitat degradation and loss for various reasons is of great concern to hippo populations across Africa. As human communities grow larger, they need to increase their agricultural outputs in order to survive. This is the cause of some conflict between humans and wildlife, as was the case in South Africa when up to 20 hippos escaped a reserve and destroyed crops on neighboring farmland (Lewison & Oliver, 2008). Irrigation of farmland also disturbs water sources and the corresponding riparian zones used by hippos (Kendall, 2011). Lastly, traditional practices continue to put stress on some populations, for example, when hippos are killed by some cultures for ceremonies (Martin, 2005).

The hippos in Sierra Leone are hundreds of kilometers away from the nearest population of common hippo in Guinea (Figure 8). The isolation of this population of hippos from other populations, makes extinction likely for them in cases of catastrophic events or rapid changes in demography or environment (Lande, 1993). Suitable habitat and/or preferred demography may be too far away to ensure the survival of the Sierra Leone population of hippos in these circumstances.

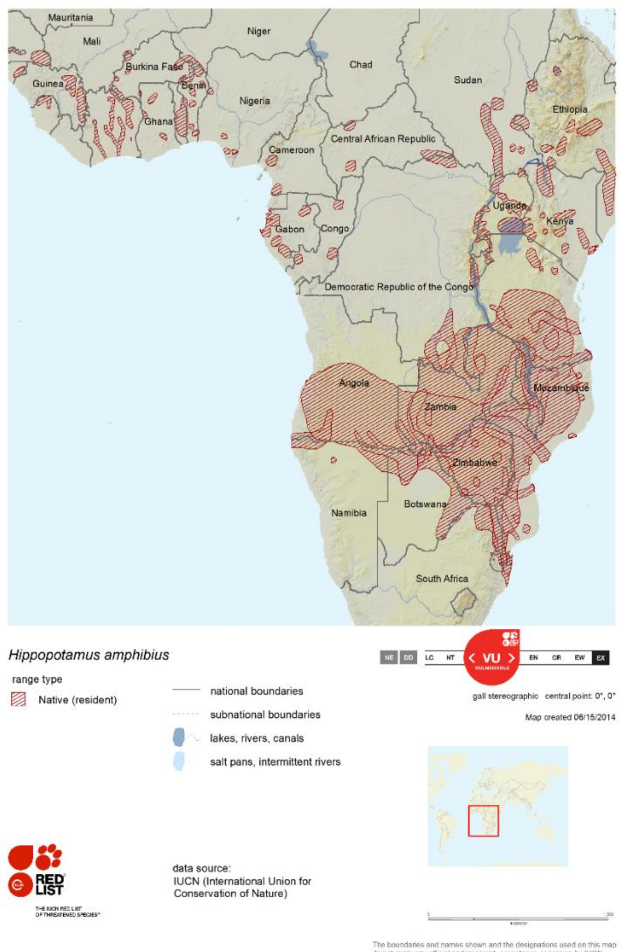


Figure 8. Current range of *H.amphibius* according to the IUCN. Reprinted from The IUCN Red List of Threatened Species, (2008), Retrieved from http://www.globalmammalforum.org/wp-content/uploads/2014/06/Hippopotamus-amphibius.png. Copyright 2014 by International Union for Conservation of Nature

With a current total population as low as 100 hippos (Table 1 and Figure 9); (Lewison & Oliver, 2008), random changes in survivability (within the year and between years) could lead to a sharp decrease in sexually viable animals (Braumann, 2010). Sexually mature females produce one calf about every two years, and it takes up to 10 years to reach the point of reproductive maturity (Eltringham, 1999). A few chance deaths of mature adults could significantly affect the hippo population in Sierra Leone.

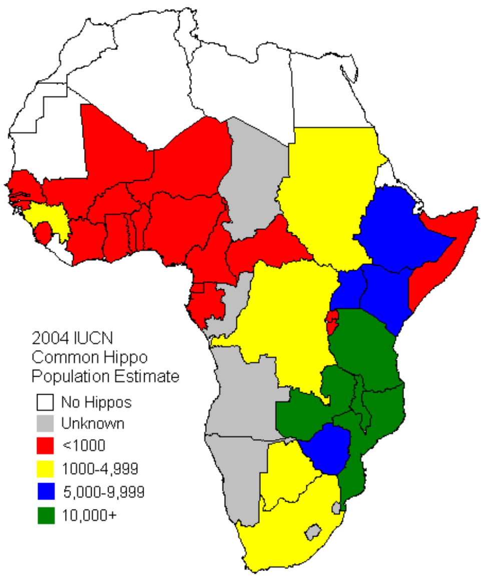


Figure 9. This map of Africa shows country-specific hippo populations, as determined by the IUCN in 2004. Sierra Leone, shown in red, contains less than 1000 hippopotami according to IUCN data. Reprinted from the Hippo Specialist Group of the World Conservation Union, n.d., Retrieved September 23, 2014, from http://www.ml.duke.edu/projects/hippos/Contacts.html

Catastrophic events are also a threat to such small populations, and frequency of these events are expected to increase with the increase in global temperature and climate variability (Thompson, Beardall, Beringer, Grace, & Sardina, 2013). Despite contributing only 2.5% of the world's anthropogenic CO^2 emissions, climate change is predicted to affect Africa more intensely than any other region of the world (Perret, 2008). Climate change models for West Africa are uncertain; temperatures are expected to rise significantly, and predictions about change in rainfall are unknown (Perret, 2008). Assuming any changes to the temperature and rainfall of West Africa and Sierra Leone, survivability and/or abundance of natural resources can be expected to change. Climate change has implications for agriculture, fisheries, disease vectors, wildlife, etc. (Perret, 2008), including the hippopotamus. If humans are strained by natural resource depletion, encroaching on valuable hippo territory is eminent. Based on the current increase of human population, along with the increase in temperature and stress on the environment due to climate change, the hippo population in Sierra Leone is in a precarious position. If the hippos begin to suffer deaths (whether it be due to hunting because of lack of other food sources, hunger, etc.) the small population may not be able to recover, and the hippopotamus will be extinct in Sierra Leone. Because of their predominantly beneficial interactions with the ecosystem, it is recommended the hippos in OKNP be protected in some way.

Poaching does not seem to be a significant problem for hippos in Sierra Leone, although it once may have been, particularly during the war when people sought refuge in the bush and relied on bush meat for survival. According to park staff, only three carcasses have been found on OKNP grounds in the memorable past, and all of those during or prior to the 1980’s (M. Mansaray, personal communication, December 17, 2013). This number may be a low estimate, as the proximity of the Guinea border may encourage hunters from Guinea to poach hippos and take them over the border, and doesn’t include any hippos that were killed during the decade-long war. Despite being seemingly safe from human hunters, hippos are directly and indirectly impacted by humans living in and around the park.

Research

Introduction

Hippopotami have been suggested to be important contributors to river ecosystems due to their amphibious habitat use, unique eating habits, and large size (Pennisi, 2014). Hippos forage predominantly on grasses beyond the riparian zone, and almost entirely during the night hours. In the morning, the hippos return to the river and remain there until the evening when they leave to forage. Except in times of extreme food shortages, hippos have not been known to forage on aquatic plants (Eltringham, 1999). Hippos thus provide a cross-boundary nutrient transfer from grassland to river, unloading large amounts of energy and organic matter from the uplands and moving it into the water. In this study we will attempt to quantify the effects of hippos (Figure 10) on the Little Scarcies river nutrients, as well as the effects of grassland removal, to support adequate protection of the species within the park.

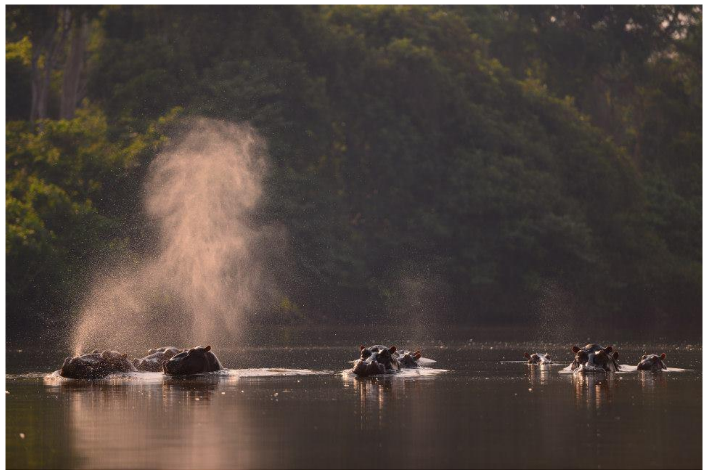


Figure 10. Hippopotamus group in Outamba-Kilimi National Park, Sierra Leone. Although some groups can reach in the hundreds, the group observed in Sierra Leone had a maximum of 12 members at a given time. Kennedy, Graeme. (Photographer). (2014, April 12).

Local villages rely on the Little Scarcies River for many of their basic daily needs, including food and water for agriculture (observation, August 9, 2013). Not only is the national park in danger of losing one of its species targeted for tourism, it could lose an important part of the ecosystem if measures aren't taken to combat the global trend of species decline. To ensure species survival, for preservation of biological diversity and to retain important food sources for local people, some type of protection should be put in place within OKNP for the current hippopotamus population despite the lack of international or governmental attention to this group. One group of hippopotami was monitored over the course of one year in order to estimate population size and determine foraging and movement trends to predict potential nutrient transport by hippos from the land to the river.   In this study we estimated the magnitude of potential nutrient inputs (carbon (C), nitrogen (N) and phosphorus (P)) by *H. amphibious* into the Little Scarcies River by counting the number of hippos in the region and using literature data to scale the counts into potential nutrient inputs to the river and foraging rates in neighboring grasslands.

The effects of *H. amphibius* on the nutrient content of the Little Scarcies River

Hippos are thought to be important resources for primary and secondary producers in river systems (Subalusky, Dutton, Rosi-Marshall, & Post, 2014), including benthic invertebrates and fish, as well as small plants (Lewison & Oliver, 2008). Waters fertilized by hippos have been noted to yield higher fish catches, (Onyeanusi, 1999) and hippos are predicted to provide substantial fertilization to primary producers in the rivers in northern Sierra Leone. Primary production in aquatic ecosystems have been argued to be limited by either nitrogen or phosphorus (Figure 11) (Vanni, 2002), significant amounts coming from hippo dung.

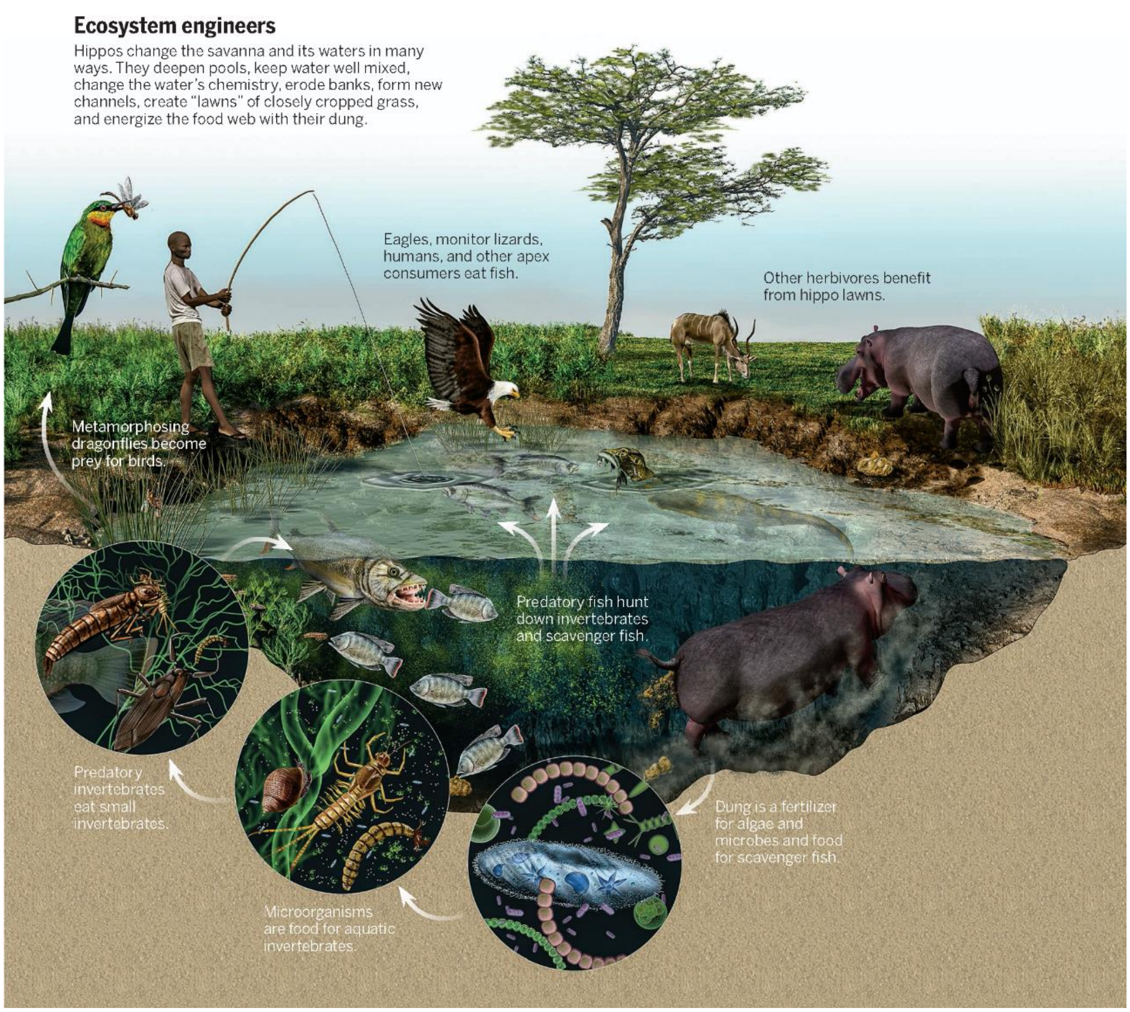


Figure 11. The food web of typical hippopotamus includes terrestrial and aquatic interactions. Reprinted from "The River Masters: Hippos are the nutrient kingpins of Africa's waterways," by E. Pennisi, 2014, Science, 346(6211), p. 805. Copyright 2014 by American Association for the Advancement of Science. Reprinted with permission.

Annual productivity removed from grasslands by *H. amphibius* in the Little Scarcies watershed

The one-way forage/excretion transfer by hippopotamus also plays a significant role in physically moving biomass from grasslands to the river (Subalusky, Dutton, Rosi-Marshall, & Post, 2014). According to Subalusky et al. (2014) hippos can consume an average of 11.0 g of dry matter per kilogram of body weight per day and they egest about half of that. For an average sized hippo of 1500 kg (Subalusky, Dutton, Rosi-Marshall, & Post, 2014), dry matter intake is estimated to reach 16.5 kg per day. Foraging generally occurs during evening/night hours after which they return to water where they continue digestion of the foraged vegetation and transfer material to the river system. Assuming constant excretion throughout the day, Subalusky et al. (2014) estimated 50% of total loading was going into water sources for the hippopotamus, and the remaining half being excreted on land. Biomass removal of this magnitude likely has important implications for the grassland ecosystem. For example, a group of 10 adult hippos, 165 kg of net primary production (NPP) is estimated to be transferred from the grassland, with only around 25% (50% of matter ingested and 50% return to the river) being returned to the grassland as N, P and C.

In order to estimate the area of hippo habitat needed to maintain the current population of hippopotami, assuming their current needs are being met, the annual removal of primary production (grasses) by Hippo group 5 will be calculated. Hippopotami in Sierra Leone are currently sharing habitat with human communities living and working on and around the Little Scarcies River. As the population of Sierra Leone grows, more grassland is being burned for farmland and hippo foraging habitat is decreasing. This influx of terrestrially derived nutrients is predicted to provide important support for local fisheries on which a large number of the people are dependent. Both hippo survival and human interests need to be considered for optimal results. Using collected data, a practical conservation method designed to protect the hippo population within Sierra Leone has been constructed.

Methods

Study Site

Outamba-Kilimi National Park is located in the Northern Province of Sierra Leone (Figure 12), Bombali District, Tambakah Chiefdom. The park is adjacent to the Fouta Jallon Highlands in Guinea, where several of the main rivers in West Africa rise (Brown &Crawford, 2012). The nearest town, Kamakwie, is about 26 km south of the Outamba-South portion of the park (Teleki, 1986), and was an important Revolutionary United Front (RUF) camp during the civil war (Squire, 2001). Within the same district there was one government-run camp, hosting refugees during the same time. This camp held almost 100,000 displaced people while it was open in 1999 (Squire, 2001). Infrastructure previously in place was destroyed or stolen during the war (M. Mansaray, personal communication, December 17, 2013).

Figure 12. Location of Outamba-Kilimi National Park in northern Sierra Leone. Reprinted from Sierra Leone, In *Encyclopedia Britannica*, 1998, Retrieved February 9, 2015, from http://www.britannica.com/EBchecked/topic/543356/Sierra-Leone. Copyright 1998 by Encyclopedia Britannica, Inc.

OKNP is surrounded by a one kilometer "buffer" zone, in which locals are allowed to legally continue traditional techniques of hunting and farming, in a limited fashion. Observations of illegal farming and fishing confirm misuse of the buffer zone according to park officials and Teleki, (1986) (Figures 13 and 14). The increase in human population size suggests these practices will continue.

Figure 13. Pepper crops on the west bank of the Little Scarcies River within the survey area (Personal photograph, 2014)

Figure 14. A temporary fishing village set up on the west bank of the Little Scarcies River within the survey area (Perry, Lindsey 2014).

Animals within the park tend to graze near the river, as it is the main source of water in the area (Kanga, Ogutu, Piepho, & Olff, 2011). While in the park I documented the following human-ecosystem interactions:

- One gunshot, despite a nation-wide removal of weapons after the civil war;
- Two tourists, along with their assigned guide, entered the study area, both on the same day;
- Mining was documented once within the study area, which consisted of about ten locals and native equipment;
- Locals in dugout canoes were spotted fishing within the study area no less than 15 times during my observations, often setting up nets the entire width of the river;
- Three temporary fishing camps set up along the river, two within the study area and one about 0.5 km south of the study area.
- At least three places along the study site where people had extended their farms to the banks of the river.

The Little Scarcies (or Kaba) river runs 161 km from Guinea, through the boundaries of OKNP, and eventually flows into the Atlantic Ocean ("Annual Statistical Digest," 2008). Technically the Little Scarcies River branches into the Kaba and Mongo Rivers at the boundary of Outamba-Kilimi National Park, but the Kaba River is commonly referred to as the Little Scarcies River (S. G. Bangura, personal communication, August 5, 2013). Survey area was determined by the location of the "Hippo 5" group, and encompassed a section of river approximately 0.633 square kilometers. The average width of the survey area was 87m, based on basic linear measurements from satellite imagery in ArcGIS. This portion of the river serves as a boundary for the park, with the buffer zone on the western side of the river. The east side of the river is within park boundaries and therefore protected land. Research was not permitted in the buffer zone.

Hippo abundance and movement

The group tracked for this study was identified by park staff as "Hippo 5," a title given to the group based on their location within the river. Hippo group size and movement were assessed in five visits to the park, between 09 August 2013 and 05 June 2014, during rainy season, beginning of dry season, and the end of dry season, resulting in twenty-five days for which hippo counts were conducted. Each day “Hippo 5” was located via canoe on the river, or on the shore if a canoe was not available for use. GPS coordinates of the hippo group during early morning, afternoon, and early evening hours were recorded, when possible. Three location coordinates were recorded for seven of 25 observation days, two location coordinates were recorded for 12 of 25 observation days, and on six days one location was recorded. Observations were taken from 20 to 30 meters from the actual group of hippos. In order to detect all the hippos in the region as individuals, each observation interval lasted at least 30 minutes, except for observations cut short for safety reasons or to collect other data ($n < 5$). GPS points were analyzed and mapped using ArcGIS.

Estimates of Hippo weight

Calves were included in the observation counts, but they were weighted proportionally based on average weights obtained for another population by Marshall & Sayer (Eltringham, 1999). Approximate weights for the older two calves were estimated by taking the average weight of hippos between zero and three years of age, and the younger calf by taking the average weight of hippos between zero and one year of age, for both male and females sampled by Marshall & Sayer in 1976 (Eltringham, 1999). These averages were compared to 1500 kg, or the average weight of an adult hippo used by Subalusky (2014). Calf weights were 19.7% and 13% of the adult weight, respectively, and therefore inputs by calves were considered 19.7% and 13% of the inputs of an average adult.

Nutrient release by hippos

Loading rates of feces, dry mass, wet mass, carbon, nitrogen and phosphorus were calculated. To determine areas of high loading rates, each observation was ranked in one of three groups, representing 1-3 hippos, 4-6 hippos and 7-10 hippos per observation. The northern boundary of the survey area was the OKNP visitor center (9°45’0”N, 12°2’23.9994”W), and the southern boundary was the farthest point downstream that hippos were observed (9°37’58.7994”N, 12°9’23.3994”W). The complete survey area was visited at least once during each of the five visits to the park.

Annual NPP removal by H. amphibius *in the Little Scarcies watershed*

During rainy season months (i.e. August, September and June) the bush was extremely thick, and in some cases too thick to pass through even with a cutlass. There was a significant amount of flooding beyond the riparian zone during these months as well. During December, we did not experience river flooding. In April, almost all of the grassland had been burned, presumably by local farmers. In order to estimate percent removal of net primary production (NPP) by hippopotami, estimates for nearby countries with similar climate were used from the literature.

Distance traveled by H. amphibius *from the Little Scarcies River for foraging*

Initially, traditional straight-line transects were attempted, in order to determine the distance travelled from the river by hippos, evidenced by signs of foraging, tracks, and scat. The first attempt to complete a transect in this way was 30 September 2013, but was hindered past 200 m from the river, due to thick bush and flooding. All subsequent transects (Figure 15) were completed by following hippo trails from access points at the water source until either the trail ended or a large foraging area was reached (Lewison & Carter, 2004). When trails diverged, the most well-worn or most recently used of the two was followed. Trails were mapped using a hand-held GPS unit (Garmin eTrex 20).

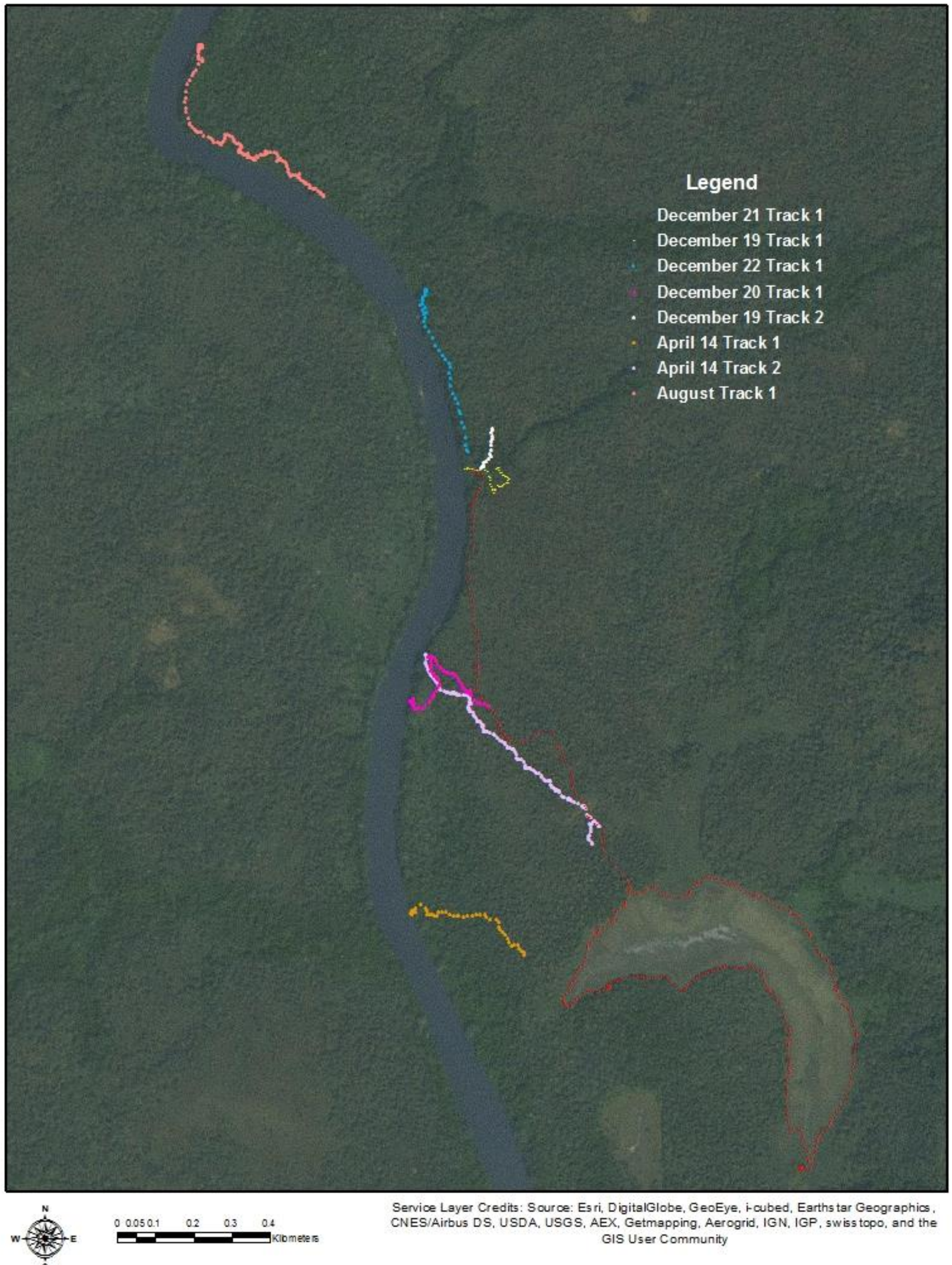


Figure 15. GPS tracks for eight active hippo paths followed during August and December 2013, and April 2014 along the Little Scarcies River, OKNP, Sierra Leone.

Results

Hippo abundance and movement

The maximum number of hippos we detected during the August, 2013 observation was nine – seven adults and two juveniles. The maximum number we detected in December was 10, suggesting one traveling bachelor. In April, 12 hippos were seen, including one newborn. With a typical sex ratio of 1:1 (Smuts & Whyte, 1981), we can then estimate that the group was made up of 4 adult females, 3 adult males, 2 juveniles, 1 newborn, and 2 traveling bachelors.

Estimates of hippo weight

We counted between 1 and 12 hippos each day, including nine adults and two calves between 0 and three years of age. Between the observations conducted during the December visit and those conducted during the April visit, another calf was born, and was considered between zero and one year of age for all calculations (Table 2).

Table 2. Hippopotamus Observations

Date	Timepoint	Total	Adults	Calf Obs (>1yr, < 3yr)	Calf Obs (<1yr)
5-Aug-13	Morning	9	7	2	0
	Afternoon	9	7	2	0
	Evening	6	6	0	0
6-Aug-13	Morning	9	7	2	0
	Afternoon	5	4	1	0
	Evening	9	7	2	0
7-Aug-13	Morning	4	3	1	0
	Evening	2	2	0	0
8-Aug-13	Morning	2	2	0	0
9-Aug-13	Morning	1	1	0	0
	Afternoon	1	1	0	0
	Evening	2	2	0	0
10-Aug-13	Evening	1	1	0	0
11-Aug-13	Morning	1	1	0	0
	Afternoon-1	1	1	0	0
	Afternoon-2	1	1	0	0
12-Aug-13	Morning	3	3	0	0
	Evening	1	1	0	0
30-Sep-13	Morning-1	4	3	1	0

	Morning-2	2	2	0	0
	Afternoon	1	1	0	0
17-Dec-13	Morning	6	4	2	0
	Evening	7	5	2	0
18-Dec-13	Afternoon	8	6	2	0
	Evening	9	7	2	0
19-Dec-13	Morning	10	8	2	0
	Afternoon	7	6	1	0
	Evening	8	7	1	0
20-Dec-13	Morning	6	6	0	0
	Afternoon	4	4	0	0
	Evening	8	7	1	0
21-Dec-13	Morning	8	7	1	0
	Evening	5	4	1	0
22-Dec-13	Morning	8	6	2	0
	Afternoon	7	6	1	0
	Evening	8	7	1	0
23-Dec-13	Morning	7	7	0	0
	Afternoon	3	3	0	0
9-Apr-14	Morning	9	7	2	0
10-Apr-14	Morning	9	6	2	1
	Morning	3	3	0	0
	Evening	11	8	2	1
11-Apr-14	Morning	9	6	2	1
12-Apr-14	Morning	10	7	2	1
	Evening	7	6	1	0
13-Apr-14	Morning	9	6	2	1
	Afternoon	7	5	2	0
	Evening	7	5	2	0
14-Apr-14	Morning	5	4	1	0
	Evening	9	6	2	1
15-Apr-14	Morning	7	6	1	0
	Evening	8	6	2	0
16-Apr-14	Morning	10	7	2	1
5-Jun-14	Afternoon	12	9	2	1
Total		325	260	57	8
Mean		6	5	1	0
Median		7	6	1	0
MIN		1	1	0	0
MAX		12	9	2	1
StError			0.316		

Table 3. Hippos observed, adults observed, and the final weighted count of hippos used to account for smaller size and input from subadults.

	Adult Hippos	Total Hippos	Weighted Count
Mean	5	6	5.0
Median	6	7	6.1
MIN	1	1	1
MAX	9	12	9.5

Table 4. Estimated weights of dry mass (DM), wet mass (WM), carbon (C), nitrogen (N), and phosphorus (P), based on weighted hippopotamus counts from observation. Figures were calculated based on nutrient data from Subalusky et al. 2014.

	Weighted Count	DM (kg)	WM (kg)	C (kg)	N (kg)	P (kg)
Mean	5.0	44	10.4	4.2	0.6	0.08
Median	6.1	53	12.6	5.1	0.7	0.09
MIN	1.0	8.7	2.07	0.84	0.1	0.02
MAX	9.5	83	19.7	8.0	1	0.1
Daily Average	11	2.9	0.696	0.28	0.04	0.01

Nutrient release by hippos

Over the entire study period (11 months) the focal group of hippos remained in a relatively small area of the Little Scarcies/Kaba River system (approximately 5.5 km of river, Figures 16 and 17).

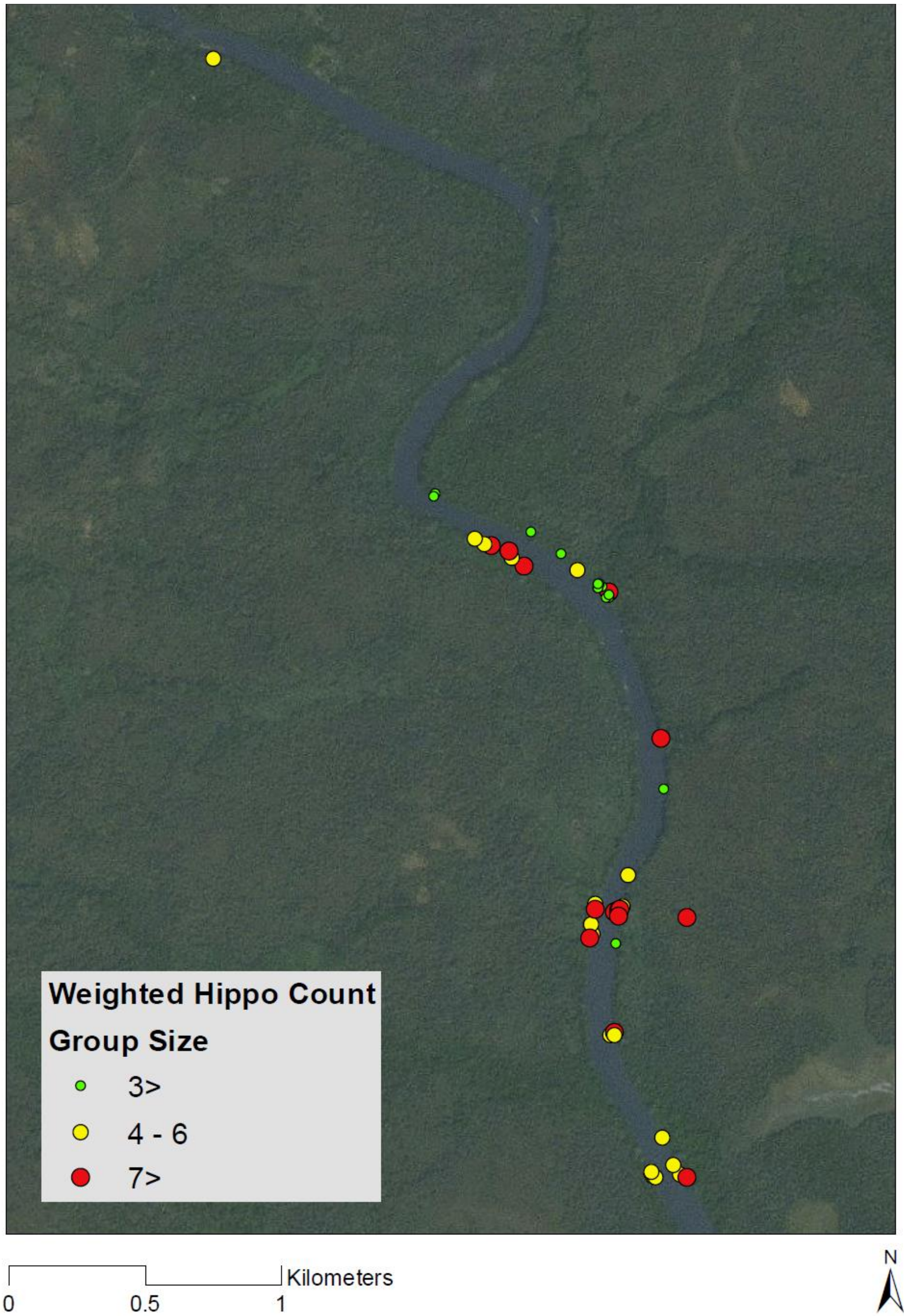
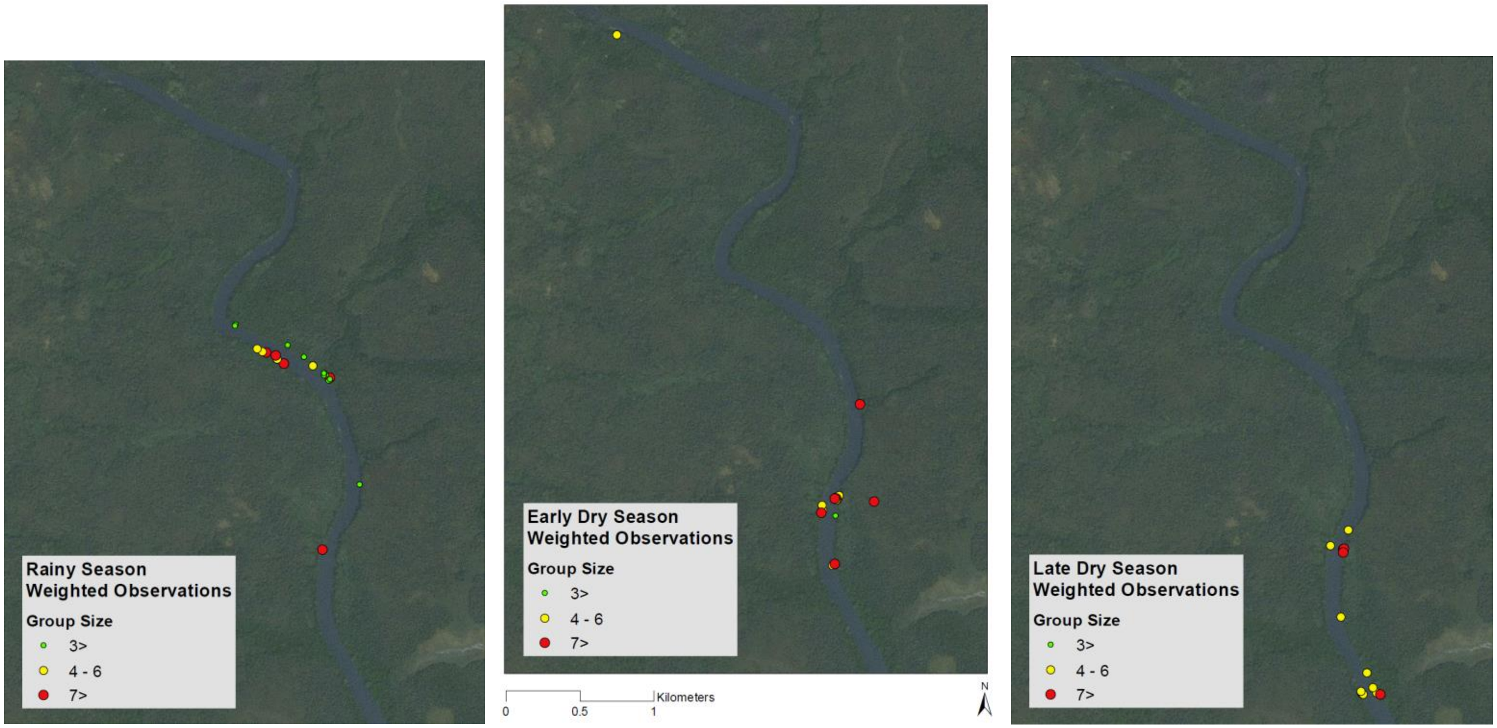


Figure 16. Locations and counts of hippos in Hippo group 5 for each observation from entire study period (August 2013 to June 2014). Counts are weighted to include subadults which are assumed to produce less fecal matter (19.7% and 13% of adult loading for subadults 0-3 and 0-1 years of age, respectively).



(a) *(b)* *(c)*

Figure 17. Locations and counts of hippos in Hippo group 5 for each observation in (a) rainy season (August and September 2013 and June 2014), (b) early dry season (December 2013), and (c) late dry season (April 2014). Counts are weighted to include subadults which are assumed to produce less fecal matter.

The section of the Little Scarcies River surveyed was approximately 3.72% of the total length of the rivers located within OKNP. Within the Scarcies river system (Little Scarcies and Great Scarcies, i.e., potential hippopotamus habitat), the surveyed section makes up about 1.39% of the total length of river. In each of the three study periods at least 9 hippos were spotted in the area at least once. The average number of hippos detected during any observation was 5.0 ± 0.3 (Mean ± 1SE). These were estimated to be contributing 44 kg of dry mass, 10.4 kg of wet mass in the form of feces, 4.2 kg C, 0.6 kg N, and 0.08 kg P into the Little Scarcies River daily. The maximum number of hippos recorded in one place along the river during an observation was 9.5, and estimated to be contributing 83 kg dry mass, 19.7 kg wet mass, 8.0 kg C, 1 kg N, and 0.1 kg P daily. The minimum number of hippos detected in one place along the river during an observation was one, estimated to be contributing 8.7 kg dry mass, 2.07 kg wet mass, 0.84 kg C, 0.1 kg N, and 0.02 kg P per day. Based on this we could estimate that our weighted max of 9.5 hippos within this reach of the river were making substantial nutrient contributions into river (Table 5).

Table 5. Sierra Leone daily hippo contributions to Little Scarcies River, compared to estimated river chemistry.

	Daily Contributions from Hippos			River Chemistry (kg/day/km^2)*				
	Hippo 5 (Mean ±1SE)	Hippo 5 (kg/day/km^2)	Avg. SL population (kg/day/km^2)*	DOC	DIN	TDN	PO4	TDP
C (kg)	4.2 ± 0.28	6.6	0.40	2340	-	-	-	-
N (kg)	0.6 ± 0.04	0.9	0.06	-	174	154	-	-
P (kg)	0.08 ± 0.005	0.1	0.007	-	-	-	5.32	15.4

*SL population and River Chemistry data were determined over the total area of riverine hippo habitat in Sierra Leone (360 km^2), while Hippo 5 data were calculated using the total study area of the river.

Hippo group 5 was estimated to be contributing an estimated 4.2 kg of carbon per day, within the 5.5 km reach of the study area (0.633102 km^2). We also estimated the total nutrient input by *H. amphibious* throughout the country by using population numbers from the literature.

Table 6. Estimated *H. amphibius* contribution to river systems in Sierra Leone based on population estimates gathered from literature accounts (Teleki 1979/80, Teleki 1986, Eltringham 1993, Eltringham 1999, and Lewison & Oliver 2008).									
		Estimated Daily Nutrient Loading by Hippos							
		WM (kg/day)		C (kg/day)		N (kg/day)		P (kg/day)	
Source	Hippo Count	Min	Max	Min	Max	Min	Max	Min	Max
a	130-190	1100	1700	110	160	16	23	2.0	2.9
b	200-280	1700	2400	170	240	21	34	3.0	4.2
c	200	-	1700	-	170	-	24	-	3.0
d	100	-	870	-	84	-	12	-	1.5
e	100	-	870	-	84	-	12	-	1.5
			Average =	140	kg/day	20	kg/day	2.6	kg/day

*These values are calculated assuming a 100% adult population, and should be considered a high estimate.
a. Teleki, 1979/80
b. Teleki, 1986
c. Eltringham, 1993
d. Eltringham, 1999
e. IUCN, 2008

Table 7. Nutrient concentrations of tropical world rivers from the literature								
	(g m-3)							Discharge
River	DOC	N-NO_3	N-NO_2	TDN	DIN	TDP	PO_4	m^3 yr^{-1}
Caura	4.5	0.07	-	-	-	0.009	-	9.47E+10
Orinoco	4.4	0.08	-	-	-	0.02	-	1.13E+12
Amazon[1,3]	5	-	-	-	-	-	-	-
Sumatra-Borneo[2]	-	0.175	-	-	-	-	0.007	2.13E+11
Niger[2]	-	0.1	0.0014	-	-	-	0.013	1.91E+11
Zaire[2]	-	0.09	0.003	-	-	0.06	0.024	1.253E+12
Orinoco[2]	-	0.09	-	-	-	-	0.0062	1.069E+12
Zambezi[2]	-	-	-	-	-	-	0.01	2.24E+11
Purari[2]	-	0.04	-	-	-	-	0.0015	7.5E+10
Mekong[2]	-	0.24	-	-	-	-	-	4.72E+11
Solimoes[2]	2	0.05	0.001	0.24	0.291	0.025	0.015	2.4E+12
Negro[2]	6.3	0.025	0.001	0.35	0.376	0.008	0.006	1.4E+12
Amazon[2,3]	5	0.04	0.001	0.275	0.316	0.02	0.012	5.5E+12
Mean	**4.5**	**0.1**	**0.0**	**0.3**	**0.3**	**0.0**	**0.0**	**1.2E+12**
Stdev	1.4	0.1	0.0	0.1	0.0	0.0	0.0	1.5E+12
Min	2	0.025	0.001	0.24	0.291	0.008	0.0015	7.5E+10
Max	6.3	0.24	0.003	0.35	0.376	0.06	0.024	5.5E+12
Median	4.8	0.08	0.001	0.275	0.316	0.02	0.01	7.705E+11

[1] – An average from 15 stations on the Amazon river in Brazil and Peru (Richey et. al., 1980)

[2] – Tropical rivers data, Table 1 (Meybeck, 1982)

[3] - Amazon discharge was only included once to discharge statistics

Based on the averages of nutrient concentrations of rivers presented in published data (Table 7), a range of 2-6.3 g m^{-3} of DOC was calculated for rivers in tropical areas. Nitrate (NO_3) was calculated to be between 0.03 and 0.24 g m^{-3}, and phosphate levels (PO^4) between 0.002 and 0.024 g m^{-3}. Nitrate and phosphate are the most commonly measured forms of Nitrogen and Phosphorus, respectively, in river systems (Meybeck, 1982). At the lowest recorded population, hippos are estimated to be loading approximately 870 kg of carbon per day into the Scarcies River system of Sierra Leone. At the highest recorded population, they were estimated to be loading about 240 kg of carbon per day, with a mean value of 140 kg of Carbon per day.

Nutrient loading by other wildlife has been presented with the data from Hippo 5 (Table 8). Although sockeye salmon are certainly contributing the largest amount of total nitrogen, it should be noted that they are contributing this amount over a period of approximately 30 days, immediately following spawning.

Table 8. Nutrient Loading By Various Animals (g m^{-2} yr^{-1} kg^{-1})

	Population (#)	# of Days in system	Area (km2)	TN	TDN	TKN	NO_3	PO_4
Hippo (Avg.)	190	365	360	0.00001	-	-	-	0.000002
Geese†	2102	120	150	-	-	0.0275	0.00001	0.005
Moose*‡	700-1200	365*	535	-	0.0002	-	-	-
sockeye salmon1∞	4361	30	6.15	0.429	-	-	-	0.0344
sockeye salmon2∞	25000	30	6.15	0.473	-	-	-	0.0387

* Moose forage in the water and excrete on land, which is the opposite effect of the rest of the species within the table.
[1]Run 1, including 4361 adults
[2]Run 2, including 2500 adults
†Unckless & Makarewicz, 2007
‡ Bump, Tischler, Schrank, Peterson, & Vucetich, 2009
∞Gross, Wurtsbaugh, & Luecke, 1998
Loading was calculated using average species weight (“Animal Facts”, 2015).

Distance traveled by H. amphibius *from Little Scarcies River for foraging*

The total distance of each of the eight hippo trails was calculated by the hand-held GPS unit, and maximum distances from the river were estimated to the nearest whole number using the Measure tool in ArcGIS.

Table 9. Length and maximum distances of hippo trails tracked in August and December 2013, and April 2014

Trail	Trail Length (m)	Max. Distance to River (m)
December 22 Trail 1	579	38
August Trail 1	948	24
December 21 Trail 1	4700	823
December 19 Trail 2	181	105
December 19 Trail 1	261	125
April 14 Trail 2	961	532
December 20 Trail 1	536	216
April 14 Trail 1	485	228

Trail lengths and maximum distances to the river were then used to determine the average length and maximum distance of hippo trails for Hippo 5 in OKNP. Maximum distance to the river was identified as the farthest point from the bank of the river throughout the entire trail length. Calculations were made with and without data from 21 December 2013, because the trail identified that day was partially man-made and went around the entire perimeter of an ephemeral lake (Lake Idrissa). There are a number of access points throughout the perimeter (Figure 15), and it is unlikely an animal would traverse this entire length at one time.

Table 10. Hippo trail calculations based on average trail length and maximum straight line distance from the river.

	(m)
Max Distance from River	823
Avg. Max Distance from River	261
Stdev of Max Distance from River	278
Avg. Trail Length	1081
Avg. Trail Length (minus Lake Idrissa)	564
Stdev of Trail Length	1489
Stdev of Trail Length (minus Lake Idrissa)	303

The maximum distance that hippos were estimated to have traveled from the river was 823 ± 278 m, which is a shorter distance traveled than those documented for various East African hippo groups (Martin, 2005; Mason, 2013; Subalusky, Dutton, Rosi-Marshall, & Post, 2014). The reason for this is likely because the hippos in OKNP have sufficient grazing areas close to the river. Other than two traveling bachelors, no other hippo groups were seen within the survey area during observations.

Annual NPP removal by H. amphibius *in the Little Scarcies watershed*

Net primary production, or NPP, can be defined as "the total organic matter produced over a given interval," (Clark et al., 2001). Calculating NPP in West Africa is challenging due to the lack of field data and Landsat imagery data, both required to accurately determine production. NPP data for Sierra Leone was not available, thus data from climactically similar countries in West Africa was used to create an estimate.

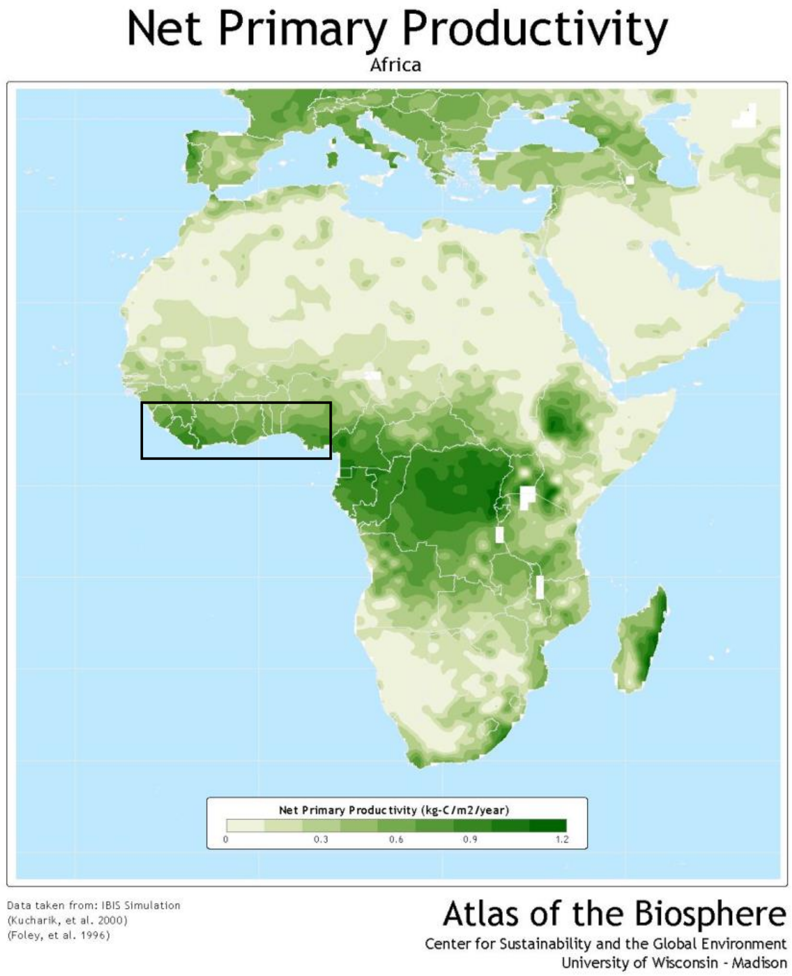


Figure 18. Net Primary Productivity for Africa. Reprinted from Atlas of the Biosphere, n.d. Retrieved March 11, 2015, from http://www.sage.wisc.edu/atlas/maps.php?datasetid=37&includerelatedlinks=1&dataset=37. Copyright 2002 by The Board of Regents of the University of Wisconsin System. Used by permission of The Center for Sustainability and the Global Environment, Nelson Institute for Environmental Studies, University of Wisconsin-Madison. The area outlined in black was added to the figure, and represents the area investigated in the current section.

The area outlined in Figure 18 has similar climate, including rainfall, and experiences similar effects from the Sahara Desert. After reviewing a list of published estimates of NPP in tropical forests, seven sites were chosen to create a reference estimate for Sierra Leone (Figure 19).

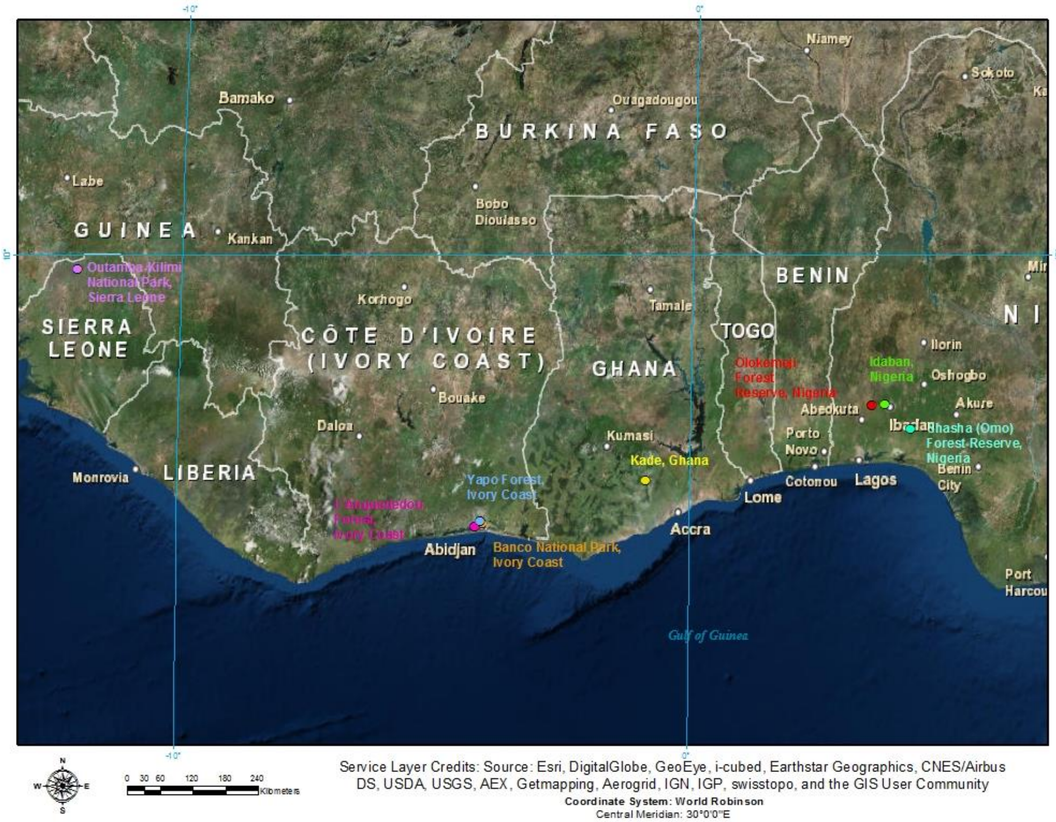


Figure 19. Seven sites of published NPP data in West Africa; Outamba-Kilimi National Park marked for reference.

Data from these countries was averaged to provide an estimate of NPP in tropical forests within West Africa (Table 11).

Table 11. Net primary production for some West African Countries used to calculate an average NPP for the region

Reference	Country	Location	t C ha^{-1} yr^{-1}
Clark 2001	Ghana	Kade	12.2
			11.0-12.5
			12.1
			12.3
	Ivory Coast	Banco National Park	8.5-11.5
			14.4
			11.4-20.9
		L'Anguededou Forest, Abidjan	17.2-31.5
		Yapo Forest	9.5-17.4
	Nigeria	Idaban	5.7
		Olokemeji Forest Reserve	10.1
		Sasha (Omo) Forest Reserve	15.7

Grace 2006	N/A	Tropical Forests	12.5
		Mean	13.7
		Median	12.3
		MIN	5.7
		MAX	31.5
		stdev	5.68

The average net primary production for published data in this region of Africa is 12.3 ± 5.68 t Carbon ha^{-1} $yr^{-1,}$ with a minimum NPP of 5.7 t Carbon ha^{-1} yr^{-1} and a maximum NPP of 31.5 t Carbon ha^{-1} yr^{-1}.

In the previous section a mean of 5.04 and a maximum of 9.52 (± 0.336 Standard Error) hippos per observation were calculated for the weighted counts obtained. From the literature, hippos are estimated to remove between 0.06 and 0.38 ha of annual production from foraging locations into the local water system every year (Subalusky et al., 2014). Using these estimates and our hippo count data, annual production removed per year was calculated for Hippo 5 (Table 12).

Table 12. Range of primary production removed by Hippo 5 every year from nearby grassland. Hippo counts include subadults weighted as a percentage of average adult hippo size (1500 kg) to account for differences in production removal.

	Total NPP From Literature (t C ha-1 yr-1)	Range of annual production removed by hippos (ha)	Carbon Removed (t yr-1)	
			Min	Max
Mean	13.7	0.303-1.92	4.15	26.3
Median	12.3	0.366-2.32	4.48	28.4
MIN	5.70	0.060-0.380	0.342	2.17
MAX	31.5	0.571-3.62	18.0	114

Range = 0.06* Weighted Hippo Count – 0.38* Weighted Hippo Count
Carbon Removed = Range Min*Total NPP from Literature, Range Max*Total NPP from Literature

Within the study area in the Little Scarcies River watershed (3.72% of the total length of OKNP rivers), hippopotami were estimated to be removing up to 3.62 ha of annual production from the grassland, and moving it by excretion and egestion to the river. These are small percentages of the total area of Outamba-Kilimi National Park (110,900 ha (Sowa, 2012)) and of the total area of the Outamba section of OKNP (74,100 ha (Sowa, 2012)). Most of OKNP is forest-grassland mosaic beyond the 823 m maximum distance traveled by hippos in this study (Table 9). We should therefore focus on the area most likely to be utilized by the hippo, i.e. grassland immediately beyond the riparian zone, to calculate the annual production removed from potential hippo habitat. If we assume hippopotami travel a maximum distance of 1 km from the river (Table 9), potential hippo habitat within OKNP is approximately 9799 ha (length of Little Scarcies River within OKNP is about 49 kilometers). Hippos may be removing up to 0.0369% of the annual production within their habitat each year. This is still probably a generous figure, as it assumes all land within 1 kilometer of the river is appropriate for hippo foraging and not inhabited by people.

Trends in access point data

All active hippo access points were documented for the study area in each season (rainy season, beginning of dry season, end of dry season). Within the study area, a total of 46 access points were identified and GPS coordinates documented (Figure 20).

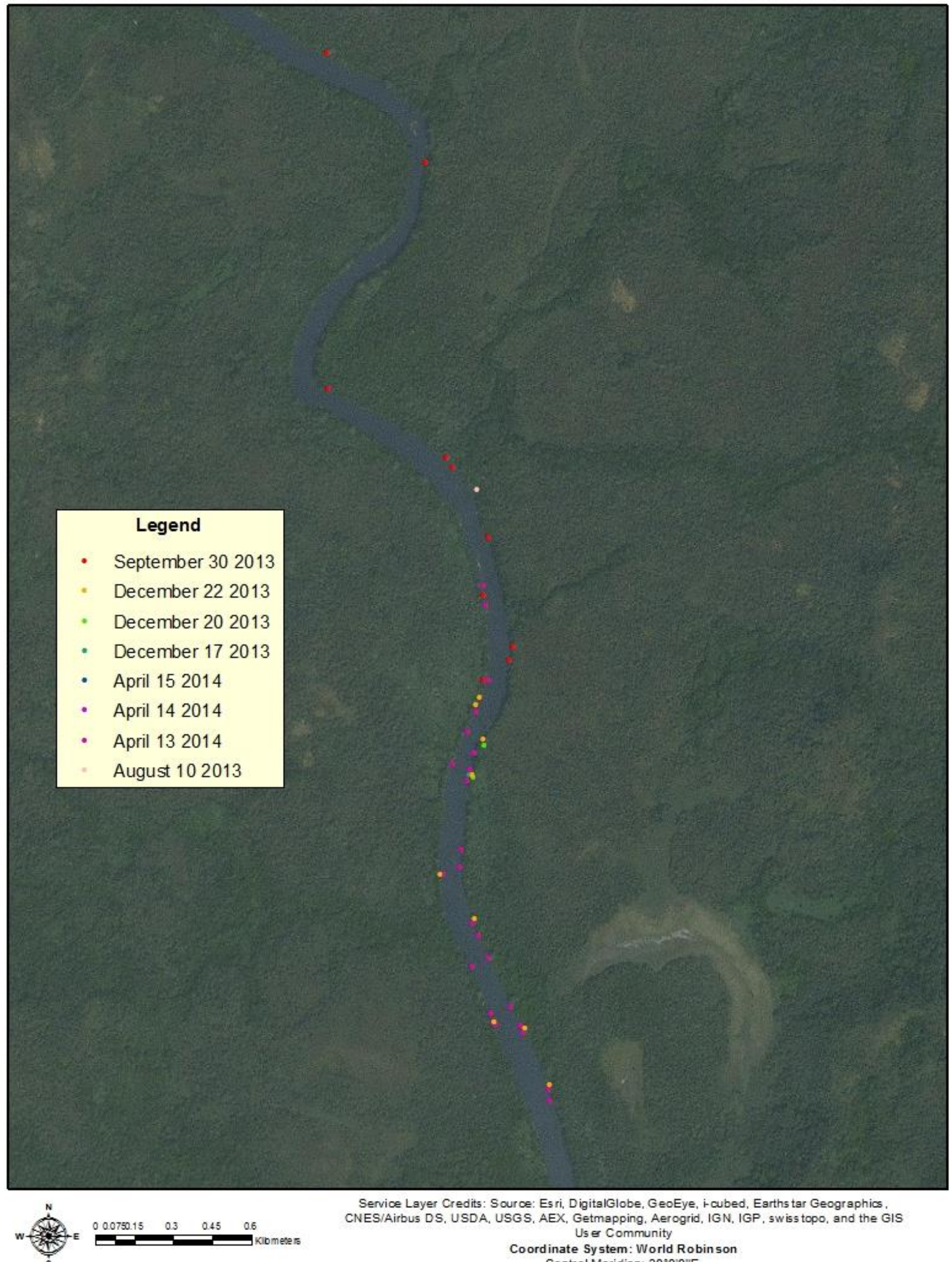


Figure 20. GPS coordinates for each active hippo access point identified within the study area during observations in August, September, and December 2013, and April 2014.

Of the 46 access points, 17 (37%) were on the west side of the river and 29 (63%) were on the east side of the river. Locals are living and working in the buffer zone illegally, and legally living and working outside the 1 km buffer zone, so hippos are most likely avoiding this area, instead choosing to exit on the east side of the river. There were also a larger number of access points documented in the dry seasons (December = 12 and April = 24) versus the rainy season (August and September = 10). During the rainy season the river rises up to the tree line and may obscure active pathways, while the end of the dry season access points are clearly seen.

Hippo tracks (Figure 15) were used to determine likely areas of foraging for the Hippo 5 group. A 1.2 km wide buffer was created in ArcGIS, to include the maximum distance traveled from the river plus 10% to ensure hippo foraging extent. From eight hippo trails, the maximum distance from the river was 1119 m, plus 10% gives a total buffer distance of 1231 m from the river. The northern and southern boundaries are based off the farthest points north and south, respectively, in which hippos were observed. An additional 100 m was added upriver and downriver from the northern most and southern most observation points, respectively, as linear territories of hippos on rivers have been found to be limited to 50 – 100 m in length (Eltringham, 1999).

Hippos in areas with year-round water supply, such as the hippos in this study, stay close to their main source of water (Lewison & Oliver, 2008). In order to ensure the survival of the hippopotamus in Sierra Leone, both park staff and people living in/near the park need to take steps to protect not only the river, but corresponding grasslands as well. The hippopotamus buffer zone created in this study (Figure 21) is a practical measure that can more easily be followed, without encroaching on basic human survival needs of the local people, and is recommended for use in the proposed conservation plan below.

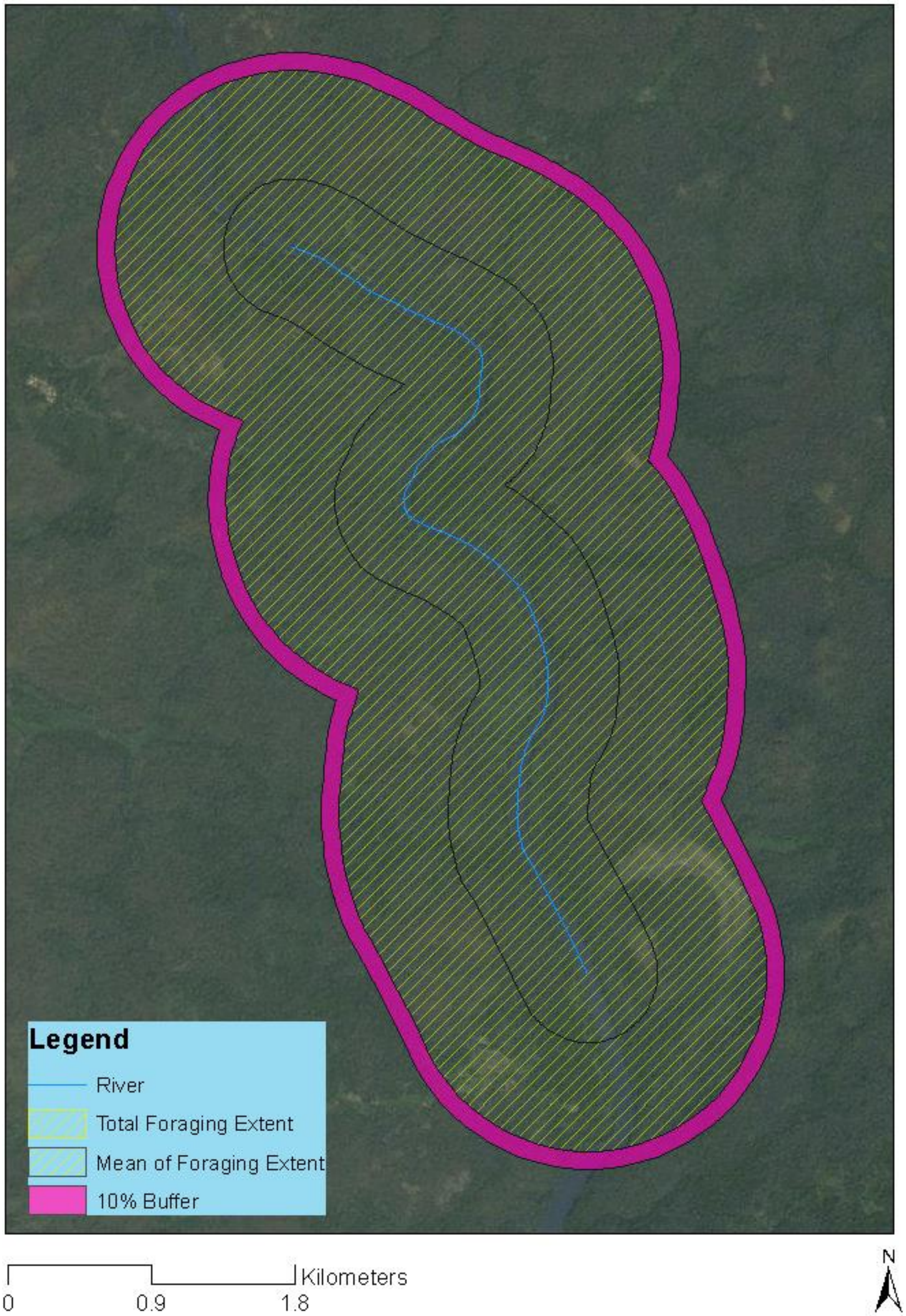


Figure 21. Proposed buffer zone for hippo group 5 protection in Outamba-Kilimi National Park, based off active hippo trails observed over one year (August 2013 to June 2014).

Discussion

The scope of this project is narrow, and was limited by both resources and time. And, while it is a crucial first step, additional attention needs to be given to important yet understudied wildlife in Sierra Leone. The meta-analyses presented in this report are adequate to estimate hippopotamus impact on Sierra Leonean river systems, but actual water chemistry data and production data would be invaluable to future research. As the country rebuilds following the recent Ebola outbreak, efforts should be made to conduct these simple tests, which would improve the quality of the data obtained during this study. What has been discovered by this investigation is the importance of considering hippopotamus contributions to the environment when constructing future conservation plans. The hippo, as well as hippo habitat, remains unprotected in Sierra Leone, and conservation efforts have been focused primarily on listed endangered species. Future conservation studies and management plans should take into consideration the large impacts our small population of hippos may have on Outamba-Kilimi National Park.

Conservation Implications

Cost of disregarding current regulations

Enforcement of rules and regulations surrounding flora and fauna of national parks in Sierra Leone is deficient. Not only are illegal farming and hunting practices common, there are too few resources to afford protection of IUCN listed species Within Outamba-Kilimi National Park there are 19 species of mammals, amphibians and birds that are considered either endangered, vulnerable or near threatened/conservation dependent by IUCN ("Protected Area Report," 2008). Out of nine primate species present in OKNP, four (western chimpanzee, red colobus monkey, black and white colobus monkey, and sooty mangabey) are considered threatened (Sowa, 2012). Large mammal populations have suffered in the past because of the lack of legislation and/or enforcement of poaching and illegal export, but most of the remaining populations can be found in OKNP. Animals that are easily seen in the park are the common hippopotamus, Green monkey, the Red and Black and White Colobus species, and various reptiles living in and around the headquarters and tourist huts. Although not easily seen, common waterbuck, African buffalo, giant ground pangolin, leopard, bushbuck, common warthog, bush duiker, forest elephant, and others are present (Sowa, 2012). In the 1980's, park staff were still estimating about 30 instances of elephant poaching per year (Teleki, 1986). Some of the species that have gone extinct in the area since colonization include the lion and the spotted hyena (Teleki, 1986). Two hundred and twenty bird species have been recorded within the park (Sowa, 2012), which may entice certain tourists up to the park as well. Historically, field surveys of flora and fauna within the park are lacking, and are especially needed with less charismatic species.

Sierra Leone's focus on human health and survival is obviously important, and cannot be disregarded. The country is fragile and recovering, but needs to consider environmental protection a way to safeguard the health and future of its people. Unsustainable resource extraction is practiced throughout the entire country on a daily basis ("Biodiversity Analysis," 2007), and cannot go on forever. There are certainly limitations with implementing conservation plans based on data from one species, but often funding and/or time do not allow complete research of ecosystem processes. The removal, whether intentional or not, of *H. amphibius* from Outamba-Kilimi National Park could have serious implications for the people living in and around the area. Park regulations should be revised and enforced within the boundaries of the park to ensure the survival of this species.

Proposed hippo conservation plan

The plan outlined in this section is not a complete conservation plan, but a practical guide for park staff, specifically designed to ensure continued existence of *H. amphibius* within the park.

Park Management

Park management is a difficult task, especially for those working at Outamba-Kilimi National Park. The park has been understaffed since the 1980's (Teleki, 1986), and has had to compete with a civil war and epidemic for attention and funding. The communities within the Outamba section of the park were never relocated, and since the war more people have settled within the park boundaries. Within the boundaries people hunt, fish, farm, and mine at will (observation, August 5, 2013). There are little to no repercussions for breaking park rules and regulations, often paying a small bribe to continue extracting resources without harassment. It's hard to argue with the park staff, who are mostly unpaid volunteers, who receive the fish and palm oil as bribes; they too are trying to survive. An important aspect of this guide is community education and strict law enforcement. If the government does not choose to fully staff the park, it is even more important for community members to understand the potential effects. They should be informed on the importance hippos play in their ecosystem, and essentially their daily survival.

In order to effectively implement a project such as this, community stakeholders need to be involved with every step. It is also important to seek additional partnerships and financial assistance. They will assist in providing the necessary funding, as well as conservation knowledge and experience. Until recently, the Biodiversity Conservation Project has been assisting park staff, but opportunities for cooperation should be continuously explored. "It is believed that institutionalized collaboration and partnership arrangements, combined with oversight coordination, could be the key to improving management effectiveness by pooling scarce resources and assigning management responsibilities and roles based on capabilities." ("Biodiversity Analysis," 2007). Universities and colleges can also provide assistance in the form of "free" research from students and frequent communication with experts in the field of conservation.

The hippo buffer zone

The creation of a buffer zone for the park did little to prevent people from continuing unsustainable use of park resources, in fact the population actually living in the park is growing (Brown & Crawford, 2012). By reducing the area in which protection is required, feasibility of follow-through by park staff, and acceptance by locals would be hopefully improved. Naiman and Rogers (1997) recommend that hippos be given unrestricted area for grazing, and allow hippo channel creation in any management plan due to their importance in the ecosystem; however, keeping people and hippos physically separated may be beneficial in this case. Physical boundaries, such as a fence, may discourage farming within the fence, as hippos have been observed to not step over very low obstacles or push through fence (Clarke, 1953), so an inexpensive wire fence may be a viable option for keeping hippos within the bounds of the buffer zone. The perimeter should also be surrounded by fire barriers, so bush fires created for agricultural purposes do not reach hippo foraging ground.

Further Research

Surveys of Flora and Fauna of OKNP

It is not adequate to only measure the impacts of hippos in this river system. Other herbivores and their ecological impacts should be considered before updating or creating new regulations within the park. That said, a complete count of hippos in Sierra Leone needs to be documented. According to Martin (2005), “standard survey techniques are unsuitable for counting hippos.” Hippos spend much of their time completely submerged under water, and it is almost impossible to identify individuals within a group. Based on my observations, I believe an accurate count of a group of hippos in Sierra Leone can be completed in a 60 minute observation period from a canoe. In order to obtain the most precise counts the entire river should be surveyed, as this is the only method which gives reliable results (Eltringham, 1999). The relatively short length of the Little Scarcies River within Sierra Leone could be surveyed quickly and accurately by two staff members using OKNP equipment, and a population estimate derived.

Transboundary Conservation

Currently, Liberia and Sierra Leone are working towards establishing a transboundary conservation plan for the Gola Rainforest National Park to strengthen conservation practices for shared areas (Brown & Crawford, 2012). Both Outamba and Kilimi sections of OKNP border;

the Fouta Djallon area of Guinea, and the Great Scarcies River makes up 101 kilometers ("Annual Statistical Digest," 2008) of the border between the two countries. These areas provide opportunities for cooperation between the two governments to strengthen conservation efforts in the area.

Hippo protection is not only important for the natural environment within the national park. OKNP could be used to educate locals on natural resource management and conservation, and as a way to bring money into the country via ecotourism. The hippopotamus is a large, charismatic species, one in which people pay to see when visiting the park (observation, April 13, 2014). Visitors to Sierra Leone come to see the megafauna and endangered species. If the park is not properly managed and protected, further attempts at ecotourism within the park are likely to fail.

Conclusion

The developing country of Sierra Leone is currently in a very precarious position, attempting to recover from a 10-year civil war followed soon after by a devastating disease outbreak. The majority of the population are subsistence farmers with little to no education, living off natural resources provided by the tropical climate. The conservation issues within Sierra Leone directly affect the future of the country. Unsustainable farming, mining, fishing and hunting practices are quickly diminishing the available natural resources ("Biodiversity Analysis," 2007). Although politically stable at the moment, human starvation due to the absence of resources could trigger instability. "There can be no durable peace if the natural resources that sustain people's livelihoods are damaged, degraded or destroyed" UNEP 2010 (Brown & Crawford, 2012).

Biodiversity within the country of Sierra Leone has decreased greatly since colonization ("Annual Statistical Digest," 2008). Outamba-Kilimi National Park is one of the few areas that has retained a certain level of biodiversity throughout the nation's tumultuous past (Teleki, 1986). It is important to protect this park to retain the biodiversity that once covered the entire country, and to preserve the natural resources for neighboring communities. *Hippopotamus* *amphibius* play an important role as ecosystem engineers, maintaining river and watershed ecosystems (Subalusky, Dutton, Rosi-Marshall, & Post, 2014) such as the Little Scarcies River system. Their large size and unique foraging habits create a large “conveyor belt” of nutrients, an average adult eating and excreting almost nine kilograms of wet mass into the water source every day. The hippos of Hippo 5 in OKNP deposit significant amounts of C, N, and P into the Little Scarcies River every year, and are also removing over one hundred tons of C per year from the neighboring grasslands in the park. If hippos and other species within Sierra Leone, aren’t permitted adequate space for survival, people will have to face the consequences in terms of lower fish catches and available bushmeat. Their large impacts on the ecosystem lend them to special protection within the park.

It is important for the people of Sierra Leone to learn to protect their natural resources, including hippos. Once Ebola has been eradicated, their economy will slowly start to rebuild, and ecotourism is an underutilized source of income for the country. In Ghana, the Wechiau Community Hippo Sanctuary was created to protect local hippo populations, and has had experienced great success (Sheppard, 2010). This sanctuary implemented a pair of buffer zones, similar in nature to the buffer zone proposed in this paper. The community economy has improved, the hippo population has remained stable, and surveys are showing an increase in biodiversity within the protected area (Sheppard, 2010). A similar project could be successful in Outamba-Kilimi National Park if community members are involved in not just implementation, but also directly benefit from the project in the long and short-term. In the initial park plans, Teleki (1986) predicted park employment to rise to over 200 people. With adequate funding from the government, park communities will not need to rely so heavily on the natural resources of the park for survival, and can instead earn an income with which to support their families.

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Appendix 1: Additional Information

Hippopotamus Behavior and Biology

Hippos spend their days in lakes or river pools, at depths where they can completely submerge, but close enough to the bank that they can use the shallower waters (optimum depth: 8-10 feet, (Clarke, 1953)) for rafting (partially submerged, resting in a group). When underwater, nostrils and ears close, allowing them to stay submerged for long periods of time (Mason, 2013). After dusk, they move up to 2-3 km from the water to forage (McCarthy, Ellery, & Bloem, 1998) generally on grasses less than 15 cm tall (Lock, 1972), and then move back to the water at dawn. During rainy seasons hippos may also spend time in tributaries or swamps that are not available during the dry season (McCarthy, Ellery, & Bloem, 1998).

Considered “megaherbivores” because of their size and foraging, adults reach 1000 to 3200 kg with males about 10% heavier than females (Eltringham, 1999), and lengths range from 290 to 505 cm (Mason, 2013). The largest hippo documented was a captive hippo in Germany, weighing 4500 kg (Mason, 2013). Hippos are considered social animals because they herd together in groups, or “schools,” of up to 200 (Lewison & Oliver, 2008), which may increase foraging efficiency, decrease predation, assist in thermoregulation, and increase survivability of young, despite the competition for resources and an increase in disease transmission resulting from grouping together (Blowers, Waterman, Kuhar, & Bettinger, 2009). Group size can range from 10-20 hippos to several hundred hippos. Groups will usually have one dominant and several subdominant males, along with many females and their calves. Infanticide by males is extremely rare, but a few cases have been documented between adult males and calves between 1-40 days old (Lewison, 1998). Causes for this could be competition for resources, post-mating competition with another male, or action to increase individual reproductive success, but should be considered an extremely rare event for this species. In more representative circumstances, young males are physically attacked and forced out of the group by the dominant male once they begin to show sexual interest in females, sometimes quite violently (Skinner, Scorer, & Millar, 1975). Typical behaviors related to displays of dominance include yawning, vocalization, and use of the canines and jaws to cause injury (Mason, 2013). Vocalizations can reach 115 decibels, and are a common type of communication between hippos (Mason, 2013). Captive hippos were observed to raft near familiar individuals (Blowers, Waterman, Kuhar, & Bettinger, 2009), although social interactions in the field are difficult to determine. In the larger groups, water is often limited and therefore hippos are forced to share one area, although they may prefer smaller groups overall (Lewison & Oliver, 2008). They forage alone at night, and are not considered territorial on land except for females foraging with and protecting their calves (Eltringham, 1999).

Hippos can live to be older than 40 years (Eltringham, 1999) and the wearing down and aging of teeth is a major contributor to death in hippos over 30 years of age (Laws, 1968). Hippos can be aged based on the condition of their teeth, although this can only be done once the hippo is deceased. Canines and incisors are used for intimidation and fighting, mastication is done with the molars, and lips are used to pull grasses (Lock, 1972). The mouth can open up to 150 degrees, and the canines and incisors can grow to lengths of 50 and 40 cm, respectively (Mason, 2013). Hippos have a high bone density and webbed feet that allow them to walk on the bottom of water bodies such as rivers and lakes capable of staying submerged for up to 30 minutes at a time (Coughlin & Fish, 2009; Mason, 2013). When on land, they are able to run at speeds upwards of 30 km/h for hundreds of meters (Mason, 2013). Hippopotamus skin is quite unique in that it allows hippos to submerge themselves in water 12 hours a day, and it plays a major role in temperature regulation (Eltringham, 1999). The skin secretes a red/brown fluid that acts as a sunscreen by absorbing UV rays (Mason, 2013), and may contain antiseptic properties that aide in healing wounds as it visibly increases in birthing females and fighting males (Eltringham, 1999).

The digestive system of H. amphibious is an interesting characteristic of the hippo. It is considered to be a “pseudo-ruminant,” which means that it doesn’t actually ruminate, but that it does have a chambered stomach (Eltringham, 1999). Whether the hippo has a three or four chambered stomach is debatable, depending on each observer’s definition of a chamber;

however, it is thought that fermentative digestion occurs within the first three chambers and gastric digestion in the fourth (Eltringham, 1999).

Hippos reach sexual maturity around six years of age for females and between nine and 10 years for males, and they have a gestation period of about 240 days (Smuts & Whyte, 1981). The age of sexual maturity is variable and depends largely on nutritional condition (Martin, 2005). Pregnant hippos leave the group before giving birth and stay separated for several weeks after the birth to feed and rest (Eltringham, 1999). When calves are born they weigh around 50 kg, and lactation lasts up to one year of age, although calves are found to have grass in their stomachs as early as six weeks of age (Eltringham, 1999). Calves continue to forage alongside their mothers until they are fully grown (Eltringham, 1999). Most births happen at the beginning of the wet season, corresponding to the availability of grasses important for foraging (Eltringham, 1999). Hippos are extremely difficult to sex because the males have a retractable penis and they lack an external scrotum (Eltringham, 1999), although if detected "large protuberances on the front of the upper jaws" can be used to identify adult males (Martin, 2005). Individuals are difficult to identify also because unique marks or scars are usually hidden below the surface of the water.

Hippos do not have any natural predators, other than humans. Unfortunately, hippos tend to be considered somewhat of a pest to the local people sharing an environment with them (Lewison & Oliver, 2008). Although hippos do not typically forage on crop plants, they have been known to trample them on the way to a more appetizing area of grasses, and they tend to use and reuse trails each night (Lock, 1972). Hippos are aggressive, charge unprovoked, and occasionally get into altercations with the local fishermen, with loss of arm as the most common injury (Eltringham, 1999). Other attacks on humans result from females defending their calves (Mason, 2013). More people are killed by hippos than by any other animal in Africa (Kendall, 2011), and the nocturnal foraging behavior may also be a result of continued interaction/avoidance of humans (Martin, 2005).

Constraints on Development

The government of Sierra Leone has made several important steps towards wildlife and environmental protection, such as the passing of the Wildlife Conservation Act in 1972 and National Environment Protection Act in 2000. Unfortunately, little has been done beyond passing legislature to conserve the country's natural resources. In 1980, American conservationist Geza Teleki wrote the current president of Sierra Leone: "If swift and decisive action is not taken by the Government there will be no wildlife left to protect within Sierra Leone." Eight years after the Wildlife Protection Act, Teleki was still concerned with the status of wildlife protection in the country. Since that time Sierra Leone has been affected by a 10-year civil war and an Ebola epidemic. These unfortunate events have left the country engrossed in basic human survival, while ignoring increasing exploitation of its natural resources.

Most residents are subsistence farmers, the mean years of schooling a mere 2.5 years ("Human Development Index," 2014). Personal experience from living in a small Sierra Leonean village confirms most villagers do not understand the idea of a non-renewable resource, and therefore live their lives as though none of their resources will run out. Farmers don't usually invest in crops that take over a year to fully develop, and focus their attentions on short-term crops for maximum gain. The economy is fueled primarily by mining, fishing and agriculture. Rice, cassava, palm oil, groundnut and peppers are grown by most families for daily sustenance, and very few farmers make an actual income with their crops. Other income comes from trading goods, and few government jobs.

Land Degradation

Mining is a big part of the economy, but often leaves areas stripped not only of ore but also trees, plants and topsoil (Carew-Reid et al., 1993). In 1969, about 12,000 square miles of the country were leased to individuals or companies for mining purposes (Clarke, 1969). More recently, mineral concessions covered 82% of Sierra Leone, compared to the meager 4% of the country covered in protected lands (Brown & Crawford, 2012). These concessions go to over

100 mining companies, both domestic and international (Brown & Crawford, 2012). Some of the minerals mined in Sierra Leone include diamonds, titanium ore, bauxite, iron ore, gold, granite, platinum and chromite ("Biodiversity Analysis," 2007; "The World Factbook," 2013). Diamond mining is popular with locals because of the simple extraction techniques, and because it doesn't require a large amount of funding to begin mining (Johnson, 2002). Many of the natural resources of Sierra Leone were depleted during the civil war, and continue to be illegally extracted today. Political and economic effects are easily seen, but many of the environmental impacts are less obvious. Large portions of land are excavated, which increases the risk of flooding in these areas which are close neighbors to villages (Hough, 2007). Flooding in any area also increases the number of pools of stagnant water (Hough, 2007), known to be essential in the life-cycles of mosquitos. Malaria is an unfortunate reality for all Sierra Leoneans, with over 1.7 million confirmed cases and over 4000 deaths in 2014 ("World Malaria Report," 2014).

Animal husbandry is limited to cattle, sheep, goats and chickens throughout Sierra Leone, with less than 2% of families owning cattle and less than 10% of families owning goats for meat ("Statistics Sierra Leone," 2007). In the northern part of the country there are many cattle ranches which are owned by semi-nomadic Fula families (Carew-Reid et al., 1993). Cattle are only slaughtered in honor of special occasions, and do not provide a consistent source of nutrition. Cattle are moved between available grazing areas until they have been exhausted, and then the family relocates with the herd. They leave behind areas of stripped vegetation, unsuitable for hippo foraging.

Humans are encroaching on hippo territory within OKNP at an alarming rate. Land degradation is the most significant stressor to the hippos in Sierra Leone. Often, commercial and artisanal mining, agriculture and timber extraction clear the forest, making way for "fast-growing woody vegetation," which upsets the ecosystem for many organisms (Carew-Reid et al., 1993). The slash-and-burn agricultural technique is utilized every year, reducing the already small area of grassland suitable for hippo foraging. Although frequently used within park boundaries, fire control is not practiced.

Protection Within Outamba-Kilimi National Park

Protection of the Great Scarcies and Little Scarcies River systems, along with the low human population in the area, made the Outamba and Kilimi sections of Tambakah Chiefdom ideal areas for protection (Teleki, 1986). Although separated by a distance of 20 km (Sowa, 2012), Outamba and Kilimi were created as one national park. Park rangers are employed through the Conservation and Wildlife Branch of MAFFS, who work alongside employees of the Biodiversity Conservation Project, a World Bank, Global Environment Facility, and Österreichische Bundesforste funded/implemented project. Many of their projects involved the endangered species within the park, including the chimpanzee and forest elephant. Other goals of the BCP were to increase community awareness of biodiversity issues within the neighboring communities, increase enforcement of environmental protection regulations and laws, and improve facilities on site (Brown & Crawford, 2012).

The villages within the entire park were supposed to be relocated and financially compensated as a part of the park project; however, the project was interrupted by the civil war and only the Kilimi section was relocated. Since that time the population of people living with the Outamba region has grown, along with an increase in agriculture and other human associated practices (Brown & Crawford, 2012).

During the civil war, lasting from 1991-2002, about 500,000 million people were displaced from their homes to the bush (Squire, 2001). There are no reliable wildlife surveys conducted after the war, but it was reported that large numbers of buffalo, hippopotamus, and primates were killed within OKNP during the war (“Biodiversity Analysis,” 2007). People were forced to seek refuge in the bush where they had to rely entirely on natural resources. The rebel forces also took to the bush for protein sources in the form of bush meat, and regularly stole harvested crops from villages when they passed through (A. Conteh, personal communication, October 10, 2013). It is likely that wildlife numbers throughout the entire country were dwindling during the war ("Biodiversity Analysis," 2007). There are many villages still within the park boundaries, including several fishing camps that move throughout the year based on water levels. There have also been up to 28 new communities that settled within OKNP over the past several years because of gold mining (Brown & Crawford, 2012).

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Figure 6

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